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OBSERVATIONS ON THE PUPAL WINGS OF NEPTICULA, WITH COMPARATIVE NOTES ON OTHER GENERA.

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The Nepticulidæ possess some conspicuous characteristics not present in other Lepidoptera. The most noticeable of these are the crowding together and anastomosis of the main tracheal stems of the fore wings and the absence of true cross-veins (except the humeral cross-vein in rare instances). The nearest approach to this type of venation seems to be found among certain small Trichoptera; where however the base of media remains distinct and does not anastomose either with radius or cubitus. The presence of a true frenulum in the male in even the most primitive genera of Nepticulidæ taken in conjunction with the fact that in the female we find both jugum on the fore wing and series of hooked spines on the costa of the hind wing also suggests their relationship to the Trichoptera. Other characteristics, such as the presence of the jugum in the female of the more primitive genera, the structure of the mouth parts, and the structure of the pupa ally them to the Eriocranid group of the Micropterygidæ.

It is in the development of the venation of the fore wings that this group differs so strikingly from other Lepidoptera. The disappearance of the basal portion of media takes place through coalescence with the base of radius or with the base of cubitus, and not through atrophy as is usual in the Frenatæ.

In the hind wing media coalesces with radius to about the middle of the wing in much the same way. This condition is not however unique, as it is occasionally present in other groups

among genera with degraded venation. In some apparent examples of media coalescing with radius, a study of phylogeny within the group will show that the result is due to the atrophy of the base of media and the approximation of the remaining one or two branches of media to the radial sector.

Within the genus *Nepticula* we find two types of venation in the fore wing. In one, probably the more primitive, media coalesces with cubitus for a short distance from the base, then passes obliquely to radius just beyond R_{2+3} and anastomoses with radius to beyond the middle of the wing. In the second type, media coalesces with radius from the base to beyond the middle of the wing. In the first type, the oblique portion of media extending between cubitus and radius appears to be a cross-vein and was formerly so interpreted. The occasional persistence of the trachea within the vein cavity of the imago, and studies on the pupal wings, to be presented below, show that this oblique vein is a part of media. Its presence in the imago indicates the coalescence of media with the base of cubitus.

The present paper is based upon studies of pupal wings of two species of *Nepticula*, viz., *N. platanella*, representing the first type of venation, and *N. rosaefoliella*, representing the second type of venation. The persistence in the imagoes of some species, of the shriveled tracheæ within the vein cavities, has made possible comparisons with other genera. Pupal wings of the more generalized forms, which might have thrown some light upon doubtful homologies as noted in the presentation to follow, were not available for study. In the figures of the wings, the single more or less wavy lines represent tracheæ; the even lines enclosing them outline the thickenings which form the future veins. The figures represent the condition of tracheæ and veins a few days before the emergence of the moth.

Fore Wings (Figs. 1, 2, and 3).

Except where otherwise noted, observations on *N. platanella* are based on the pupal wing illustrated by Figure 1.

Costa.—In *N. platanella* (Fig. 2) at a period before the developing vein cavities are clearly defined, the costal trachea is distinct. Later (Fig. 1) it is much shortened and extends

for merely a short distance into the base of the costal vein, not reaching the humeral cross-vein. In *N. rosaefoliella* (Fig. 3) no costal trachea could be distinguished.

Subcosta.—The subcostal trachea is distinct and branched near its tip in *N. platanella;* Sc_1 (except early as shown in Fig. 2) is shriveled and curled even in the pupa, while Sc_2 passes straight onward to the margin of the wing. There is no indication of branching in the subcostal vein of the imago in which trachea Sc_2 extends to the end; the shriveled stump of Sc_1 occasionally persists within the subcostal vein. In *N. rosaefoliella,* the subcostal trachea is unbranched, that portion persisting being Sc_2. The humeral cross-vein is easily visible in *N. platanella,* and I have found it present in all specimens examined; it passes obliquely from subcosta to costa near the base. In the imago it arises almost at the base of the wing, so oblique as almost to seem a proximal prolongation of costa.

Radius.—With the exception that R_{2+3} is represented by an unbranched trachea, the tracheation in *N. platanella* approaches closely to that of the hypothetical type. The tracheal stem of radius branches dichotomously, about half way between the base of the wing and the point of separation of vein R_1 from the main radial stem, into an unbranched trachea R_1, and into a stem which again divides dichotomously, also before the separation of vein R_1, into a second unbranched trachea, R_{2+3} and into R_{4+5}, so that for a short distance the developing vein cavity contains three tracheal branches lying closely along side of one another. R_{2+3} follows R_{4+5} for a short distance before diverging toward the costa. A little beyond the point of separation of R_{2+3}, the trachea of R_{4+5} divides, the branches however lying close together in the same vein cavity until near the apex of the wing, where they diverge, each lying in a separate vein cavity. The relation of tracheæ to veins in *N. rosaefoliella* is in essential agreement with that observed in *N. platanella,* except that (1) the branching off of tracheæ R_1 and R_{2+3} occurs at or near the point of separation of the corresponding veins and (2) there is no division of trachea R_{4+5} until very near the margin of the wing (cf. fig. 3) and but a single unbranched vein is formed.

In the imaginal wing of the European *Trifurcula,* the main stem of the persistent radial trachea divides dichotomously into

R_1 and R_{2+3}; further branches of radius (both tracheæ and veins) are entirely wanting. In the adult wing of the European *Scoliaula*, the separation of vein R_1 occurs at the point of origin of trachea R_1, which is very near the base; otherwise the tracheation of radius, as far as persistent, is similar to that of the pupal wings of *N. platanella*.

Media.—In all species of *Nepticula*, media is represented by an unbranched vein which reaches the wing margin below the apex. In the pupal wings of both species examined, a single trachea extends from base to wing margin, with no discernible trace of branching. In *N. platanella*, the basal portion of this trachea lies within the same vein cavity and alongside of the base of the cubital trachea, from which it diverges to pass obliquely to radius just beyond R_{2+3}, lying alongside of and in the same vein cavity with the radial trachea to beyond the middle of the wing where it again diverges before the separation of veins R_4 and R_5, and passes to the margin of the wing below the apex. In one specimen (Fig. 2), at an earlier stage of development than that shown in Figure 1, and in which the vein cavities were not as well defined, the medial trachea does not approximate as closely to cubitus at its base, nor to radius in the middle of the wing, so that the relative positions of the basal stems of the main tracheæ approach more nearly to those of the hypothetical type. In *N. rosaefoliella*, the trachea of media lies alongside of and in the same vein cavity with radius from the base of the wing to its point of divergence from R_{4+5} beyond the middle of the wing. An intermediate condition is to be noted in *N. variella*, where media coalesces with cubitus at base, but passes to radius before the point of separation of R_1.

Because of the unbranched condition of the medial trachea it is impossible to determine with certainty the homology of the vein which it precedes.

In *Obrussa* and *Glaucolepis* media is two-branched; in the former genus, the separation of the branches occurs beyond the separation of media from R_{4+5}; in the latter before the separation of media from radius. In *Obrussa*, the tracheæ in the imaginal wing are not sufficiently persistent for study. In *Glaucolepis*, the medial trachea is unbranched and shrivels up near the point of separation of the first of the two branches of media. However, as all of the branches of the radial trachea are distinctly

preserved along the middle of the wing, as is also the cubital trachea (which here lies alongside of media for its whole length), it might be expected that if the second branch of media were M_{3+4} it would be represented by a remnant of a trachea branching off about as far from the base as the second dichotomous division of radius, and certainly not farther distad than the separation of R_{4+5} into its branches. No such remnant is discernible and I have therefore interpreted the branches of media in these two genera as M_1 and M_2 respectively.

In the genera *Scoliaula* and *Trifurcula*, in the adult wing, three veins which reach the margin below the apex arise from the main vein traversing the middle of the wing, which, as shown by the persistent tracheæ within the vein cavity, is formed by the coalescence of the basal stems of the radial sector, media and cubitus in *Scoliaula*, and by the coalescence of media and cubitus in *Trifurcula*. The medial trachea so far as it persists is unbranched in both. The first two veins may without doubt, as in the previous case, be regarded as M_1 and M_2, respectively. As far as any evidence presented by the tracheæ is concerned, the third vein may be either M_{3+4} or cubitus. In most other genera, as noted immediately below, cubitus tends to become obsolete before reaching the margin; if the same course of development has been followed here, the conclusion would be that the third vein is M_{3+4}.

Cubitus.—In *N. platanella* the unbranched cubital trachea passes almost straight from base to beyond the middle of the wing, where it becomes obsolete. As before mentioned, in the proximal part of its course, it lies within the same vein cavity as media. In *N. rosaefoliella*, the cubital trachea lies alone in a separate vein cavity. A condition similar to that in *N. platanella* is found in *Ectoedemia* and *Obrussa;* in *Ectoedemia* cubitus usually reaches to the margin, in *Obrussa* it atrophies shortly after its separation from media. In *Glaucolepis* cubitus has entirely coalesced with media in its proximal portion and with the radio-medial stem beyond. In *Scoliaula* the cubital trachea lies in the single vein cavity in which are also the medial and radial tracheæ, and from which R_1 separates near the base. In *Trifurcula* the cubital trachea, which lies in the same vein cavity as media, branches dichotomously at the same distance from the base as the branching of radius; these branches persist to about the middle of the wing.

Anal Veins.—There are two anal veins. The first is here regarded as the homologue of the second anal vein of the hypothetical type, because of its relation to the anal furrow, because it occupies the same position as the second anal vein in other Lepidoptera, and because of its identical structure with that vein in some Trichoptera. In both species studied the trachea is distinctly visible within the developing vein cavity extending almost or quite to the end of the vein; the trachea usually persists in this vein in the imago. The third anal vein is sometimes present. In *N. platanella* it shows merely as a short spur from the base of the second anal vein, in which even in the pupa, no trachea is visible. In *Scoliaula* it is better preserved and portions of the trachea persist.

HIND WINGS (Figs. 4 and 5).

Observations on the pupal hind wings were confined to *Nepticula platanella.*

Costa.—No costal trachea was discernible. Figure 5 represents the venation and tracheation in a wing just after emergence. The costal vein is seen to be connected at the base with the subcosta, apparently by a much shortened humeral cross-vein, much as in the fore wing.

Subcosta and R_1.—Early in pupal development the trachea of subcosta and R_1 are widely separated and R_1 leaves the radial stem very near the base, as shown in Figure 4. At emergence they are more closely approximated and enclosed within the same very broad vein cavity. A similar condition may be noted wherever the tracheae persist.

Radial Sector and Media.—The radial sector is reduced to a single unbranched trachea lying in its proximal half in the same vein cavity with the medial trachea. The medial trachea and vein in *N. platanella* are unbranched as is also the case in the other species and genera, except in *Glaucolepis* and *Trifurcula* where the vein is dichotomously branched. In *Glaucolepis* the medial trachea is also dichotomously branched near the base and before the separation of radius and media; one branch running into each of the branches of the medial vein. From this it would appear that the first branch of media is M_{1+2} and the second M_{3+4}. In *Trifurcula* the trachea is single and extends into the first medial branch.

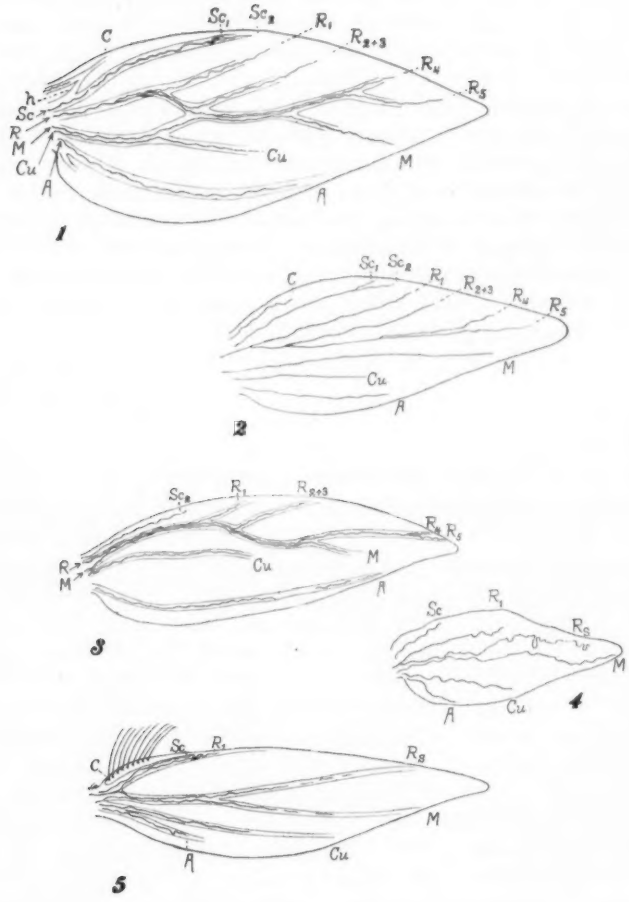
Cubitus.—The cubital trachea is unbranched, and in the earlier pupa extends nearly to the wing margin.

Anal Veins.—At least one anal vein is present preceded by a trachea which often persists in the imago. In some species and genera, a second short anal vein is present, but no trachea persists.

The question of homology of wing veins among forms with degraded venation, as is often the case in the Microlepidoptera, sometimes presents a puzzling problem, which in many cases can only be solved by a study of pupal wings; involving as has been hinted in the above presentation of the pupal wings of *Nepticula*, a study of the more generalized as well as the most specialized wings within the group, since the tracheae show the same tendency toward reduction in number of branches as is seen in the wing veins of the imago.

EXPLANATION OF PLATE XVIII.

Fig. 1. Pupal fore wing of *Nepticula platanella* a few days before emergence.
Fig. 2. Pupal fore wing of *N. platanella* at an earlier stage than that represented by Fig. 1.
Fig. 3. Pupal fore wing of *Nepticula rosaefoliella.*
Fig. 4. Pupal hind wing of *N. platanella* of the same age as the fore wing in Fig. 2.
Fig. 5. Hind wing of *N. platanella* just after emergence.



Annette F. Braun.

THE PHYLOGENY OF THE ELATERIDAE BASED ON LARVAL CHARACTERS.

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The object of the present paper is to accentuate the value of studies of the larval characters in attempting a natural classification of the Coleoptera, and to present a new arrangement of the Elateridæ based upon such studies. The paper is preliminary and based largely upon the external characters of the larvæ. Seventy-nine names have been recognized at one time or another for genera occurring in our fauna, but, after considering synonomy and misidentification, this number can be reduced to between forty and fifty. Practically all of the common holoartic genera are represented. Specimens of the larvæ of thirty-eight genera have been studied. The fourteen or more genera whose larvæ are still unknown are as follows: The genus *Melanactes*, containing seven species, two of which are quite common; the genus *Esthesopus*, containing six species; *Paranomus*, four; *Leptoschema*, three; *Oxygonus*, *Eniconyx* and *Meristhus*, two each; and *Nothodes*, *Bladus*, *Elatrinus*, *Blauta*, *Oedostethus*, *Aptopus* and *Coptostethus*, one each. In the absence of reared material, the characters of the genera *Ischnodes*, *Ectinus*, *Adrastus*, *Hypnoidus* and *Lepturoides* were drawn from literature. With these exceptions, the larvæ of species representing all the genera herein treated were examined by the writer and the generic characters drawn from the last larval exuvium of individuals of which the imago was reared and carefully determined. In many of the genera several species were examined.

I wish to express my sincere gratitude to Mr. E. A. Schwarz, of the U. S. National Museum, without whose kindly assistance the work would have been impossible; to the late Professor F. M. Webster, who permitted the use of the material in the Division collection; to Mr. H. S. Barber, who facilitated the use of the Museum material; to Mr. C. W. Johnson, of the Boston Society of Natural History, who very kindly allowed me to use the material in the Thaddeus Harris collection; and to Dr. A. D. Hopkins and Mr. F. C. Craighead, of the Division of

Forest Insect Investigation, for the use of their very valuable material. I am deeply indebted to Dr. Adam Böving, of the same Division, who gave invaluable assistance in homologizing the sclerites in several genera, and who helped in countless other ways, both with material from Europe and his broad knowledge of Coleopterous larvæ.

The principal works consulted were: Schiodte[1] (1861-69), Perris[2] (1852-1863), Candeze[3] (1861), Henriksen[4] (1911), and Gahan[5] (1911), and also the principal works on classification of the adult beetles.

Before proceeding with the classification of the Elateridæ as we now understand this family, I will briefly discuss the older group *Sternoxes* of Latereille[6] (1802). This is still recognized by such renowned authorities as Kolbe (1901) and Gahan (1911) to be a natural super-group. Lacordaire[7] (1857) subdivided this group into six families, the Elaterides, Cerophytides, Cebrionides, Eucnemides, Throscides and Buprestides, which with but few changes, have stood to the present time. Drs. Leconte and Horn (1883) in their classification reduced the Cerophytidæ, Cebrionidæ and Eucnemidæ to subfamilies, erecting an additional subfamily, the Perothopinæ, to include the genus *Perothops* formerly included in the Eucnemidæ, but rejected from that family by de Bonvoluoir in his Monograph. This last author retained the Cerophyidæ in the Eucnemidæ, but Leconte and Horn believed that it should represent a subfamily connecting the Eucnemidæ with the Dascyllidæ. Kolbe (1901) re-established these families, adding the Dicronychidæ which is considered by Gahan (1911) to be very closely related to the Plastoceridæ of the more recent authors and which I reduce to subfamily rank. The classification herein proposed agrees with that of Kolbe[8] (1901) in elevating the Leconte and Horn subfamilies to family rank, but would indicate the relationship of these families by establishing a superfamily Elateroidea.

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[1] Metamorphosi Eleutheratorum Observationees, 1861–69. Classification of the Buprestidae and Elateridae (Natur. Hist. Tidssk., Ser. 3, Vol. III, Copenhagen, 1865.

[2] Histoire des Insects du Pin Maritime (Ann. Soc. Ent. France), 1852-63.

[3] Histoire des Metamorphoses de quelques Coleopteres Exotiques, Liege, 1861.

[4] Oversight over de danske Elateridae-larvae (Entomologie Meddelelser, part 2, Vol. IV, 1911.

[5] Classification of the Coleoptera (The Entomologist, Vol. XLIV), 1911.

[6] Hist. Nat. etc. Tome III, p. 99, 1802.

[7] Hist. Nat. des Ins. Col. IV, p. 1-246, 1857.

[8] Arch. fur Naturg. 1901, p. 39.

I do not consider the Buprestidæ as at all related to this superfamily, and have not yet studied the Throscidæ. Mr. F. C. Craighead has very recently loaned me a larval exuvium of *Drapetes geminatus* Say. This species, heretofore referred to the Throscidæ, is certainly very closely allied to the Elateridæ of the subfamily Oestodinæ in its larval characters. Through the kindness of Dr. Böving I have received specimens of *Throscus dermestoides* from Mr. C. E. Rosenberg, of Copenhagen, which are most assuredly not closely allied to the Elateridæ, and conclude that on the present evidence it will be necessary to remove the genus *Drapetes* from the Throscidæ.

The hitherto supposed relationship of the Elateridæ and Buprestidæ, using the Eucnemidæ as the connecting link, is undoubtedly erroneous, the larval resemblance being purely superficial. The characters formerly used to differentiate the Eucnemidæ from the Elateridæ have failed to hold even with the few specimens I have examined. They are not as has generally been conceded, universally apodus as is clearly to be seen in an undoubted Eucnemid larva occurring in rotten logs in the Eastern States, in which distinct, though rudimentary, legs are evident. The mouthparts are adapted to wood boring, so their unique structure cannot be given overmuch taxonomic weight, and the tenth abdominal segment is situated ventrocephalad to the ninth as in the Elateridæ. The careful anatomical studies made by Schiodte[9] (1847 and 1865) of the adults separate the Elateridæ and Buprestidæ very widely. The old group *Sternoxes*, as we now understand it, consists of three groups: the superfamily Elateroidea; the family Throscidæ, part of which may eventually be placed in this superfamily; and the family Buprestidæ. The superfamily Elateroidea embraces the families Cerophytidæ, Cebrionidæ, Plastoceridæ, Elateridæ and Eucnemidæ. The Cerophytidæ and Plastoceridæ are unknown as larvæ. Their very doubtful position cannot fail to be somewhat more positively determined by their larvæ when these are described. The plate (Fig. 1) indicates in outline the various concepts of this complex.

[9] (Naturhist. Tidssk. ser. 3, Vol. III, 1865) and Konge. Danske Viden. Selsk. Forh. 1847).

STERNOXYS LATREILLE.

CONCEPTION OF LACORDAIRE	CONCEPTION OF KOLBE	PRESENT CONCEPTION	CONCEPTION OF GANGLEBAUR	CONCEPTION OF LECONTE & HORN
Fam. ELATERIDAE	Fam. ELATERIDAE	Super Fam. ELATEROIDEA	Fam. ELATERIDAE	Fam. ELATERIDAE
Fam. CEROPHYTIDAE	Fam. CEROPHYTIDAE	Fam. Cerophytidae		Sub. Fam. Cerophytinae
Fam. CEBRIONIDAE	Fam. CEBRIONIDAE	Fam. Cebrionidae	Fam. CEBRIONIDAE	Sub. Fam. Cebrionidae
	Fam. PLASTOCERIDAE	Fam. Plastoceridae		
		Sub. Fam. Dicronychidae		
		Fam. Elateridae		Sub. Fam. Elaterinae
Fam. EUCNEMIDAE	Fam. EUCNEMIDAE	Fam. Eucnemidae	Fam. EUCNEMIDAE	Sub. Fam. Eucneminae
		Sub. Fam. Perothopinae		Sub. Fam. Perothopinae
	Fam. DICHRONYCHIDAE			
Fam. THROSCIDAE	Fam. THROSCIDAE	Fam. THROSCIDAE (excluding *Drapetes*)	Fam. THROSCIDAE	Fam. THROSCIDAE
Fam. BUPRESTIDAE	Fam. BUPRESTIDAE	Fam. BUPRESTIDAE	Fam. BUPRESTIDAE	Fam. BUPRESTIDAE

FIG. 1.

The larvæ of the Elateridæ, as here restricted, are distinguished by the following characters: (1) The lower mouthparts inserted, that is to say, the hypostoma strongly curved caudad and the maxillary stipes and cardo inserted far behind the mandibular articulation. (2) Labrum not defined; it may be aborted or it may be fused with the post-labrum and front into the nasal lobe. (3) Spiracles of the biforian type. (4) Three-jointed antennæ. (5) Well-developed thoracic legs. (6) Unguiform tarsi. (7) Tenth segment ventrocephalad to the ninth. (8) No cerci. (9) Mandibles not perforate as in some Lampyridæ, etc.

Schiodte, using larval characters, divided the Elateridæ, in which he also included our present families Cebrionidæ and Eucnemidæ, into two main groups, basing his conclusions on the presence or absence of anal armature. Group 1 contained the Eucnemidæ and group 2 the Elateridæ and Cebrionidæ. He subdivided his Elateridæ, in the narrow sense, into main divisions A and B, the former embracing *Cardiophorus*, *Chalcolepidius*, *Alaus*, *Agrypnus* and *Lacon;* the latter the remainder of the family as known to him, including the Cebrionidæ. With the exception of the genus *Cardiophorus*, I include all the genera of his division A in my tribe Pyrophorini. He separated his second division into categories on the shape of the ninth abdominal segment. The first of these categories, those species without posteriorly directed paired prongs, includes the genera which I refer to my subfamily Elaterinæ, and the second, in which occur manifestly paired prongs on the ninth abdominal segment, includes the genera referred to the tribe Lepturoidini of my subfamily Pyrophorinæ.

Henriksen follows Schiodte in using the presence or the absence of anal armature to primarily subdivide the Elateridæ into the tribes Agrypnini and Elaterini. This division is not at all natural as it widely separates such manifestly closely related forms as *Limonius* and *Ludius* Esch. (which we have been erroneously calling *Corymbites*) and brings together such distinct tribes as the Steatoderini and Athouini. A much more natural division is based upon the depressed body, visible and membraneous pleural areas, and emarginate ninth abdominal segment; in contrast with the cylindrical, highly chitinized body, concealed pleuræ, and entire ninth abdominal segment.

This conclusion is strengthened by the systematic arrangement of these insects as conceived by the more eminent workers of the group and based almost exclusively on adult characters.

The first, third and fourth tribes of Candeze (1857)* Agrypnides, Hemirhipides, Chalcolepidides, fall naturally under my Pyrophorini. His second tribe, Melanactides, is still unknown in the larval stage and we can expect much light to be thrown upon its phyletic position when the larvæ are described. Candeze states that the tribe serves as a connecting link between the Agrypnides and the Hemirhipides. The type genus of the tribe was established by LeConte (1853) for several North American species placed by Eschscholtz in his *Ludius* and by Germar in *Pristilophus*, both genera now usually considered as *Corymbites* Latr. Whether the larvæ of these insects will show a relationship between my tribes Pyrophorini and Lepturoidini or will reduce the tribe Melanactides to synonomy under one of the other tribes, remains to be discovered. He includes in his seventh tribe, Elaterides vrais, the Pyrophorina and Monocrepidina, which I consider should be placed at the end of the tribe Pyrophorini as the transient forms between the two tribes of this subfamily, and not at all closely related to the other subtribes which he places in this tribe. Excluding these two groups of genera, the tribe Elaterides vrais agrees with the primary division of Schiodte and Henriksen, and may have suggested the high ordinal value that these more recent writers gave to the presence or absence of anal armature. Candeze's division of his two great tribes into subtribes, however, is remarkably illuminating from our view point, in many respects bearing out the conclusions here set forth. His subtribe Ludites includes the tribes Steatoderini and Agriotini of my subfamily Elaterinæ. His Campylites, which he places at the end of his classification and considers very distinct from the other tribes, I place at the end of the tribe Lepturoidini, though undoubtedly many of the genera in the Campylites will be found to belong in other tribes than that of the type genus. In his later work† (1891) Candeze disregarded the two tribes of his Monograph and raised all his subtribes to tribal rank.

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* Monogr. des Elat. Tome 1, (1857).

† Cat. Method. des Elat. 1891.

Leconte and Horn (1883) agree with Candeze (1857) in tribal arrangement, except that they reduce Campylites to a subtribe under the Athoui, which I believe to be much nearer to the true position of the genus *Campylus* than that given by Candeze. Their division into subtribes, based primarily upon the shape of the posterior coxal plates, has led them into some very grave errors and seems to indicate that the form of the "plaque nasale" used by Candeze as of primary importance has much higher ordinal value. Their subtribe Corymbitini includes such widely separated forms as *Pyrophorus*, which belongs to my subfamily Pyrophorinæ, *Athous*, belonging to the same subfamily, but tribe Lepturoidini; *Agrypnus*, belonging to the same subfamily, tribe Pyrophorini; *Sericosomus*, belonging to the subfamily Elaterinæ and tribe Steatoderini; and *Melanotus* to the tribe Melanotini. Their subtribe Elaterini includes *Monocrepidius*, of my subfamily Pyrophorinæ, tribe Pyrophorini; *Cryptohypnus*, of the same subfamily but in tribe Lepturoidini; *Tricophorus*, of the subfamily Elaterinæ, tribe Steatoderini; and *Elater* and *Megapenthes*, of the tribe Elaterini.

O. Schwarz (1906) in Genera Insectorum follows Candeze (1891) with but few exceptions. He raises Candeze's Plastocerini to family rank; adds the tribe Octocryptini to receive the single genus *Octocryptus* Candeze; Physodactylini to include several genera from South America and Africa; and changes six tribal names in accordance with the rules of nomenclature.

Pyrophorinæ.

My first subfamily, the Pyrophorinæ, is characterized by having the larvæ (Fig. 2) dorso-ventrally depressed, with the ninth abdominal segment emarginate posteriorly, and the pleural areas membranous and visible; while in the adult the front is usually flat or concave, the "plaque nasale" when present is wide and the antennal fossæ small.

This subfamily is divided into four tribes, the first of which, the Pyrophorini, is characterized in the larvæ (Fig. 2) by having the submentum triangular, bases of stipes-maxillæ contiguous, and mandibles without teeth on the inner surface; and in the adults, by the absence of the cubital cross vein in the wings. This vein is present in all the other groups with but one or two exceptions, which will be mentioned later.

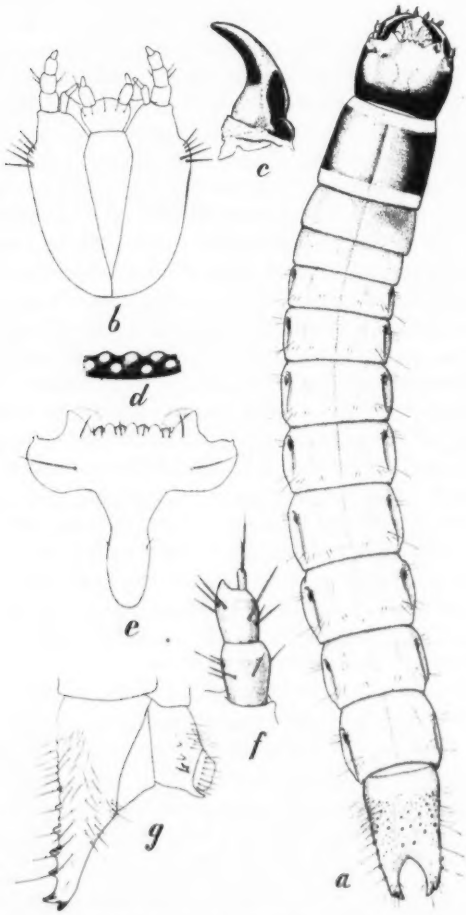

Fig. 2. *Pyrophorus luminosus* Illig. a, dorsal aspect of larva; b, ventral aspect of labium and maxillae; c, ventral aspect of left mandible; d, anterior aspect of nasale; e, nasale and front; f, antenna; g, lateral aspect of 9th and 10th abdominal segments.

The second tribe of the Pyrophorinæ, the Pityobini (Fig. 3), is characterized in the larval stage by having the submentum triangular and the mandibles with three teeth on the inner surface. The adults have flabellate antennæ in the males; a distinct transverse carina on the front above the "plaque nasale;" joints two to four of the tarsi with short

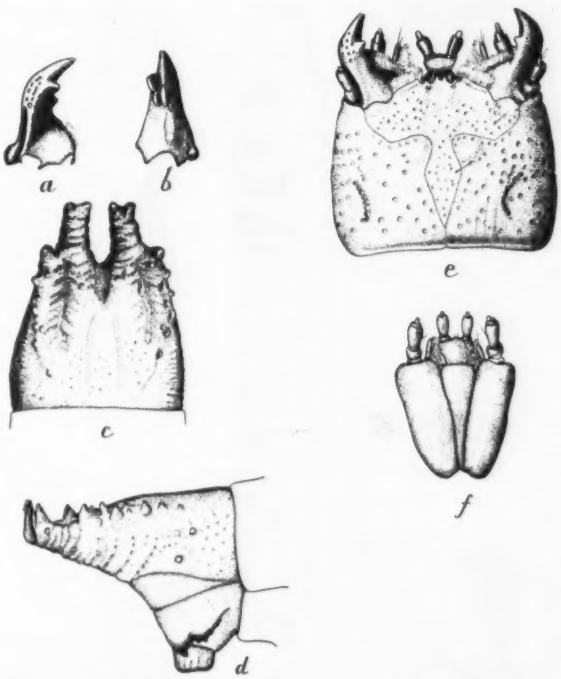

Fig. 3. *Pityobius anguinus* Lec. a, dorsal aspect of left mandible; b, inner aspect of same; c, dorsal aspect of 9th abdominal segment; d, lateral aspect of 9th and 10th abdominal segments, (10th reconstructed); e, dorsal aspect of head; f, labium and maxillae.

lobes and the first tarsal joint longer than the two following joints united. This tribe is of remarkable interest as it is intermediate between the two main subdivisions erected by Schiodte and Henriksen, having the retinaculum of their second tribe and the triangular submentum of their first tribe. This bears out my conclusion that the shape of the ninth abdominal

segment, and general shape of the body, are of higher ordinal value than the presence or absence of anal armature.

The third tribe, Lepturoidini, is easily separable in the larval stage (Fig. 4) from the other two tribes in the first subfamily by having the submentum broad caudad, that is to say, the

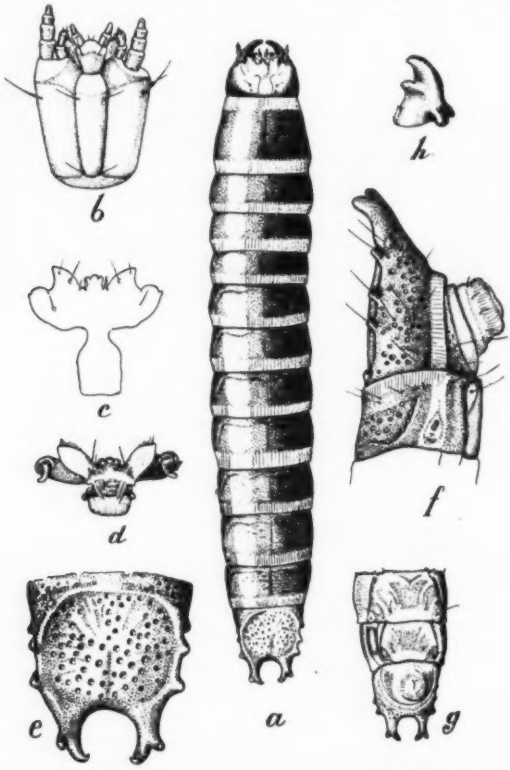

Fig. 4. *Athous cucullatus* (Say). a, dorsal aspect of larva; b, ventral aspect of labium and maxillae; c, nasale and front; d, anterior aspect of same; e, dorsal aspect of 9th abdominal segment; f, lateral aspect of 8th, 9th and 10th abdominal segments; g, ventral aspect of 7th to 10th abdominal segments; h, ventral aspect of left mandible.

stipes-maxillæ widely separated by the posterior part of the submentum; by the absence of armature on the tenth abdominal segment; and by having teeth on the inner surface of the mandibles; while the adults have the cubital cross vein present.

The tribe Oestodini is tentatively placed in the first subfamily but undoubtedly is much more widely separated from the other three tribes than these are from each other and, as has already been mentioned, is very similar to the so-called Throscid, *Drapetes geminatus* Say. The larvæ (Fig. 5) are distinguished

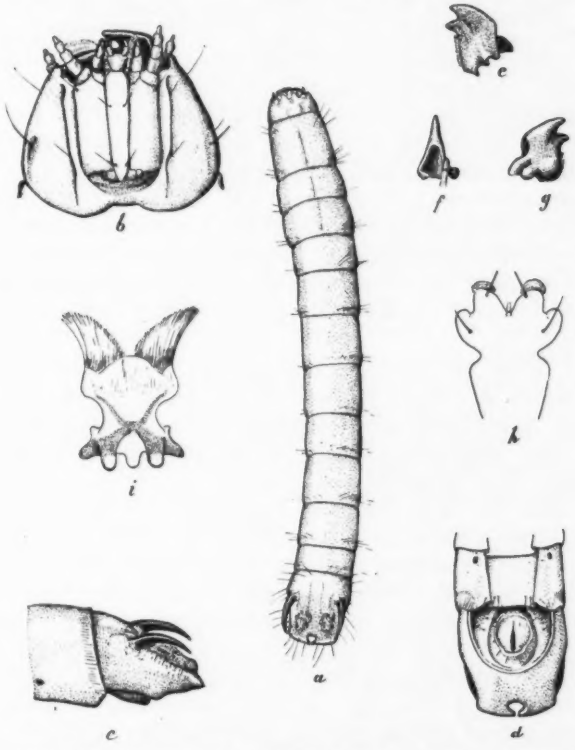

Fig. 5. *Oestodes tenuicollis* Rand. a, dorsal aspect of larva; b, ventral aspect of head; c, lateral aspect of 8th, 9th and 10th abdominal segments; d. ventral aspect of same; e, dorsal aspect of right mandible; f, lateral aspect of same; g, ventral aspect of same; h, front; i, hypopharyngial chitinization.

by the absence of a "nasale," that is to say, the forepart of the fronto-clypeal region is concave instead of being produced into a dentate plate as in all other Elaterid larvæ; the mandibles have a pronounced tooth on the inner edge; and the

ninth abdominal segment bears two caudally directed stout, curved prongs on its dorso-cephalad surface. The adult is characterized by having the prosternum very short anteriorly, thus leaving the under mouthparts exposed; by having the meso-coxæ contiguous; and the front not carinate, in this last respect being very similar to our subfamily Elaterinæ. Heretofore the insect upon which this tribe is established, *Oestodes tenuicollis*, has been placed in the Campylites. This is undoubtedly erroneous. The larva of the type species of the genus *Campylus* has been described by Schiodte (1861-1869) and by Henriksen (1911) and the similarity of this larva and also the adult of the typical *Campylus* and *Athous*, leaves but little doubt that the Campylidinæ (Lepturoidinæ) are not in a tribe by themselves, but very closely related to the Athouina and in no way whatever related to *Oestodes*. It is barely possible that Schiodte did not actually have the larva of *Campylus denticornis* as this insect is certainly easily distinguished from *Athous* on adult characters.

The tribe Pyrophorini includes five generally accepted tribes which are here reduced to subtribal rank. The first subtribe, Agrypnina, is distinguished in the larval stage by the simple anal armature, simple mandibles and triangular submentum. The Hemirrhipina includes the Alaites of Candeze (1891) and the Hemirrhipini of authors. It is distinguished by the simple mandibles in the adult stage and by the presence of the meso-metasternal suture. The Chalcolepidina are distinguished by the absence of the meso-metasternal suture, being the only Elaterids in which this suture is not well defined. This character is of rather questionable value, however, as *Alaus* is so extremely similar to *Chalcolepidius* in many very important characters that it is questionable whether this genus should be placed in the Hemirrhipina or in the Chalcolepidina. Leconte and Horn placed *Alaus* and *Chalcolepidius* in the same tribe, excluding *Hemirrhipus*. The wing venation of the two genera is almost identical; the cubital cross vein arising at the base of the first fork of the cubitus and the radio median cross vein arising at about the middle of the median cell. The Pyrophorina are distinguished from all other Elaterids by the luminous vesicles of the prothorax. The "nasale" in the larvæ has, on its anterior border, seven blunt teeth

arranged in two rows, three in the upper and four in the lower row. The mandibles are simple and the armature of the tenth abdominal segment consists of accessory spines in addition to the anal hooks, found in all the tribe Pyrophorini. The subtribe Monocrepidina is characterized in the larval stage by the triangular submentum; tridentate "nasale;" simple mandibles; decidedly reduced anal armature. This last character showing a transition from the highly complex armature of the tenth abdominal segment of the Chalcolepidina and Hemirrhipina to the unarmed tenth abdominal segment of the Lepturoidini. The adults are characterized by the broadened posterior coxæ, and convex front, which are exceptional characters in this tribe.

The first subtribe of the Lepturoidini, the Athouina, includes *Athous*, *Limonius*, *Pheletes*, etc. The adults have the anterior carina of the front well developed, the posterior coxæ but slightly broadened inwardly, and the tarsal claws simple. The second subtribe, the Ludiina, includes the genera *Cryptohypnus*, *Hypnoidus*, *Ludius* (Corymbites auct.) *Hemicrepidius*, etc. The genus *Cryptohypnus* is exceptional in that the cubital cross vein is absent. The subtribe Lepturoidina includes those members of the old tribe Campylidini which are closely related to the genus *Campylus* as distinguished from those of the *Oestodes* tribe. The three subtribes of the Lepturoidini are not as yet separable on larval characters.

Elaterinæ.

The second subfamily, the Elaterinæ, is characterized by having the larvæ (Fig. 6) cylindrical or subcylindrical in general form, the ninth abdominal segment never emarginate, and the pleural areas always concealed or decidedly reduced; the adults have the front usually convex, the "plaque nasale" narrow when present, and the antennal fossæ large. This subfamily is divided into five tribes: the first, the Steatoderini, includes *Sericosomus*, *Trichophorus*, *Orthostethus*, etc. The larvæ (Fig. 6) have the ninth abdominal segment smoothly ellipsoidal and the tenth abdominal segment extremely small.

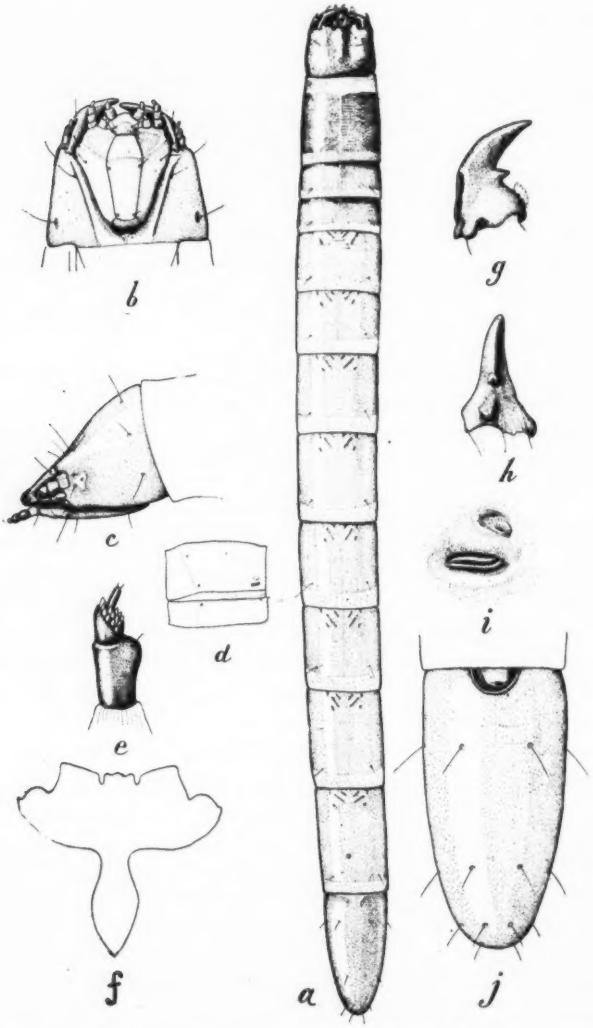

Fig. 6. *Orthostethus infuscatus* Germ. a, dorsal aspect of larva; b, ventral aspect of head; c, lateral aspect of head; d, lateral aspect of abdominal segment; e, antenna; f, nasale and front; g, ventral aspect of right mandible; h, inner aspect of same; i, abdominal spiracle; j, ventral aspect of 9th and 10th abdominal segments.

The second tribe, the Agriotini, includes *Agriotes*, *Dolopius*, *Ectinus*, *Adrastus*, *Betarmon*, etc. The larvæ (Fig. 7) are characterized by having the "plaque nasale" tridentate; the ninth abdominal segment more or less bluntly pointed caudad,

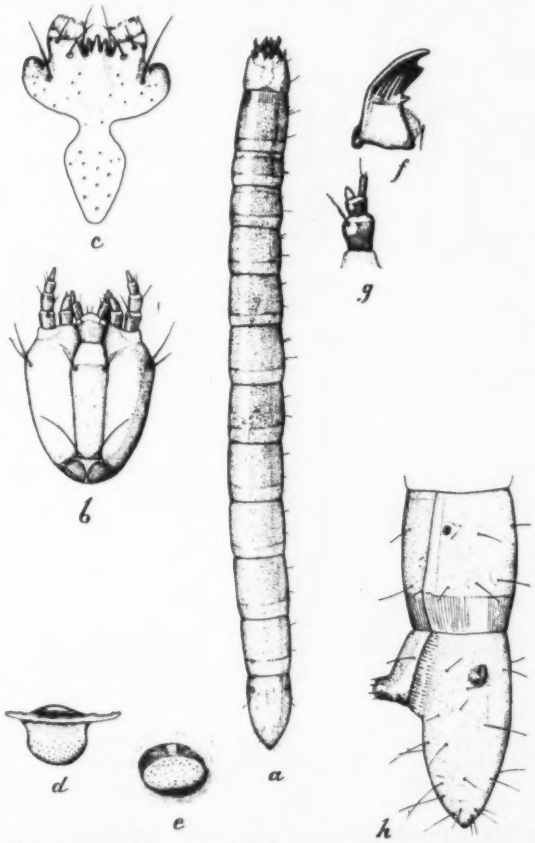

Fig. 7. *Agriotes mancus* Say. a, dorsal aspect of larva; b, ventral aspect of maxillae and labium; c, nasale and front; d, lateral aspect of invagination on 9th abdominal segment (dissected out); e, same from inside surface of integument; f, ventral aspect of right mandible; g, antenna; h, lateral aspect of 8th, 9th and 10th abdominal segments.

never smoothly rounded as in the Steatoderini, nor bearing a conspicuous terminal spine as in the Elaterini. The adults have the front strongly convex and lack the transverse carina, the mouthparts being directed downward.

The tribe Elaterini is characterized by the larvæ (Fig. 8) having the "nasale" unidentate; the ninth abdominal segment ending in a conspicuous spine; the transverse muscular impressions on the abdominal tergites very conspicuous.

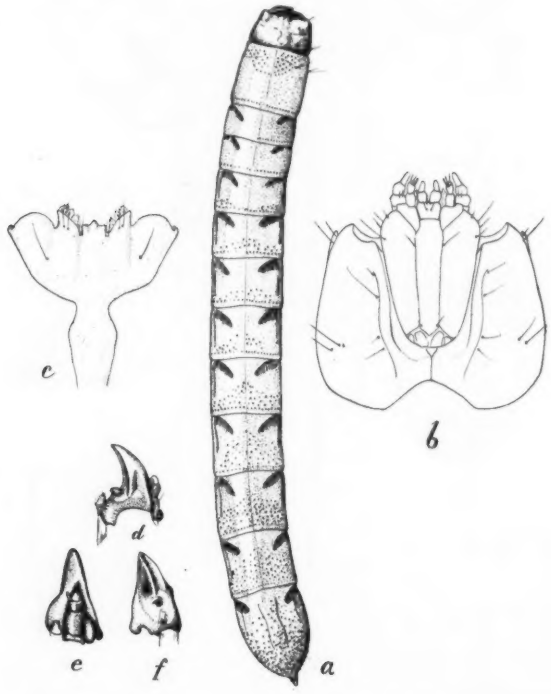

Fig. 8. *Ischiodontus oblitus* Cand. a, dorsal aspect of larva; b, ventral aspect of head; c, nasale and front; d, dorsal aspect of right mandible; e, lateral aspect of same; f, inner aspect of same.

The tribe Physorrhini is tentatively maintained to receive *Anchastus*. This tribe has been recognized by the leading authorities in this group and I have not had opportunity of examining positively determined larvæ. A larva tentatively determined as *Anchastus* bears strong resemblance to the larva of *Dolopius*.

The tribe Melanotini is characterized in the larval stage (Fig. 9) by having the ninth abdominal segment dorso-ventrally compressed caudad and ending in three lobes. The adults are easily recognized by the pectinate tarsal claws, being the *only tribe* in the subfamily in which this character is present.

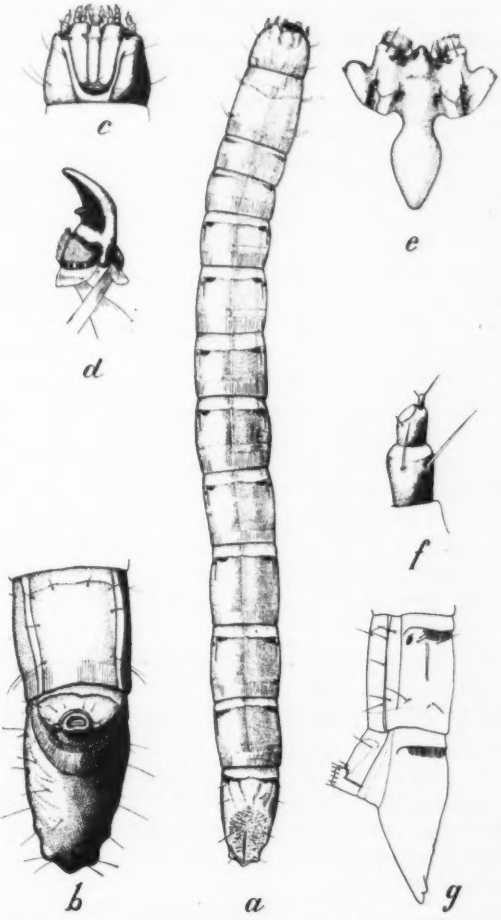

Fig. 9. *Melanotus sp.* a, dorsal aspect of larva; b, ventral aspect of 8th, 9th and 10th abdominal segments; c, ventral aspect of head; d, ventral aspect of left mandible; e, nasale and front; f, antenna; g, lateral aspect of 8th, 9th and 10th abdominal segments.

The tribe Steatoderini is subdivided into the two subtribes, Sericosomina to include the genus *Sericosomus*, and Steatoderina to include *Trichophorus*, *Orthostethus*, etc. The strongly convex head of the larva of *Sericosomus* and the broad penta-tuberculate mandibles with the single sense process (Böving 1910) on the second antennal segment easily distinguish members of this subtribe. The Steatoderina (Fig. 6) are the only Elateridæ bearing more than one sense process on the second antennal segment.

The tribe Agriotini is subdivided into the subtribes Agriotina and Adrastina. Agriotina (Fig. 7) is characterized by two deeply pigmented invaginations of the epidermis on the base of the ninth abdominal segment. These are not connected with the tracheal system and their function is problematical; they occur nowhere else in the Elateridæ as far as we know. The Adrastina agree with the Agriotina in the adult condition, but the larvæ are easily separated by the absence of the above mentioned invaginations and by the presence of transverse rows of setiferous tubercules on the ninth abdominal segment. *Betarmon* is hardly distinguishable in the larval stage from those species referred to our subtribe Adrastina. The adults have been referred to the tribe Pomachilini, which tribe is diagnosed by Candeze largely on habitus. They approach in one direction the Agriotina, in another the Elaterina and in another the Physorrhina. The tribe is probably a miscellaneous collection of genera which will eventually be referred to other tribes. *Ectinus*, the larva of which has been described by Henriksen, does not fall in either of these categories, but undoubtedly belongs in this tribe.

The tribe Elaterini is subdivided into the Elaterina and the Dicrepidina. In the former the transverse muscular impressions on the tergites of the abdomen are parallel with the anterior and posterior margins of these tergites, while in the Dicrepidina (Fig. 8) they are obliquely placed upon the tergites. The adults in the subtribe Elaterina never bear lobes on the tarsi, while in the Dicrepidina the second and third joints at least are lobed.

Cardiophorinæ.

The subfamily Cardiophorinæ includes the single tribe Cardiophorini and is characterized in the larval condition* by the membranous integument of the body, by the accessory digitate anal lobes, by the mandibles bearing teeth upon the exterior surface, and by the spiracles being placed upon retractile papillæ. The adults are easily distinguished by the truncate prosternal spine and the cordiform scutellum.

Addenda.

The placing of the following tribes in this classification is merely suggestive as no larvæ are known from any species contained therein and my conclusions are based entirely upon adult characters.

The first of these tribes, the Oxynopterini, is composed of four genera, and is characterized by the very excavate front, protuberant simple mandibles, simple tarsi, very elongate maxillary palpi, and the extremely broad metathoracic epimera. Hope separated this tribe from the other Elateridæ, erecting therefor a family, the Phyllophoridæ. The tribe seems to bear affinities with *Campsosternus* and *Tetralobus*.

The second, the Tetralobini, consists of the remarkable African Elaterids of the genus *Tetralobus*. Enormous insects measuring from 30-80 mm. in length, and characterized by the "plaque nasale" being as broad as long; mandibles dentate; antennæ strongly flabellate in male; and the tarsi lobed. They are probably closely related to the Oxynopterini.

The third unplaced tribe, the Eudactylini, which Candeze places with much reservation near the Dicrepidiini, is characterized by having the frontal carina well defined; the prosternal sutures fine and straight; tarsal joints short, very much dilated and often lamellate and the claws simple.

The fourth tribe, Crepidomini, lacks the frontal carina, the front flat or concave and usually acuminate; posterior coxæ gradually narrowed inwardly; and joints two to four of tarsi dilated. The tribe is confined to the Australian region and is allied to Ludiina and Lepturoidina.

* Figured in Bureau of Ent. Bull. n. s. 156, p. 8, Fig. 3b, 1915, and in greater detail in Proc. Ent. Soc. Wash. XVII, p. 179–185, Pl. 20, 21, 1915.

The fifth tribe, the Allotriini, lacks the frontal carina; the front more or less concave; and tarsal joints three and four lamellate at least on anterior tarsi. This tribe is closely allied to the next.

The sixth tribe, the Dimitini, also lacks frontal carina; front slightly declivious and flat; posterior coxæ incomplete exteriorly, that is to say, obliterated at the point nearest the metathoracic epimera. This is a very small tribe in which is placed the anomalous genus *Anthracopteryx* of Horn.

The seventh tribe, Hypodesini, is erected for the single genus *Hypodesis* of Central America and Mexico and distinguished by the convex front; large antennal fossæ; frontal carina obliterated above the point of insertion of labrum; super-antennal ridges oblique and short; mouth inferior; tarsal joints two, three and four lamellate; and tarsal claws simple. Intermediate between the Dimitini and the Cardiorhini.

The eighth, the Cardiorhini, is a very natural tribe and easily defined by the large bilobed labrum, which character alone suffices to distinguish these insects which are inhabitants of Tropical America. All the species belong to the genus *Cardiorhinus*. This tribe, with the three preceding, cannot even be placed hypothetically until the larvæ have been discovered.

The ninth, the Physodactylini, is a tribe erected by O. Schwarz in Genera Insectorum (1906) to receive five small genera from Africa and South America, all of which, with the exception of the type genus *Physodactylus* formerly referred to the Cebrionidæ, are quite recent.

That many discrepancies will be found in this arrangement of the Elateridæ is inevitable, for though I have examined larvæ of most of the holarctic genera, only a sparse representation of the world's *Elateridæ* are known. The holarctic fauna is extremely weak in Elaterid representatives as compared with the more tropical regions. The great centers of Elateridæ at the present time seem to be the Indo Malayan region and Tropical America. Larvæ of but one or two genera from these regions are known. About six thousand species of Elateridæ have been described for which five hundred and forty-eight genera have been erected. Therefore, we have seen representatives of less than one-tenth of the known genera in the family.

That this classification is on a much firmer basis than one depending entirely upon adult morphology, needs no confirmation. Many taxonomists have questioned the advisability of attempting to apply to the insects the axiom of the general zoologist, that ontogeny bears out phylogeny, that is to say, that the history of the race is borne out by recapitulation in the history of the individual. They contend that, though undoubtedly the evolution of the race leaves its impressions upon the successive stages in the ontogeny of the extant representative of that race, the insect larva is so actively associated with its environment that adaptive variations will entirely obliterate these phyletic inheritances. Though this is undoubtedly true in a certain degree, and must be considered when reviewing larval characters, it has been overstated, at least in the Elateridæ. Representatives of nearly all the tribes are found in a variety of habitats much more diverse than the habitats of many families of mammals, yet they retain the phyletic characters so as to leave no doubt whatever as to their relationship. For example, larvæ of the genus *Melanotus* are found in rotten logs, in cultivated fields, under stones, in forest moss, and in mud. No one would question the relationship of the various species of *Melanotus*, and their larvæ, even under these extremely different habitats, are almost inseparable. Larvæ of the genus *Elater* are found in rotten logs, in the stems of mushrooms, under stones, and under lichens on exposed boulders, yet an *Elater* larva can be recognized at a glance, and no important phyletic characters have been obscured by adaptive modifications. I believe it more logical to accept ontogenic evidence, with reasonable reservation, than to blindly follow adult comparative morphology, without taking into consideration the enormous possibility of error on account of convergent variation due to the fact that the adult Elaterids are much less diverse in habits than are their larvæ. As far as we know their habits, they all frequent flowers and leaves and are exclusively phytophagous, while the larvæ live in practically all habitats, except the truly aquatic, and are both carnivorous and phytophagous.

The Schematic tree (Fig. 10) is arranged to express my concept of the phylogeny of the Elateridæ, of which the larvæ are now known. The vertical elevation of the origin of the

various branches is but very roughly indicative of a relative time displacement. The lateral arrangement of the genera is intended to indicate the superficial relationship of the present day genera. The sub-families Pyrophorinæ and Elaterinæ evidently branched off in the quite remote past.

The paleontological record has recently been carefully studied by Professor Wickham,* who has presented a most excellent review of our knowledge of the fossils of these insects.

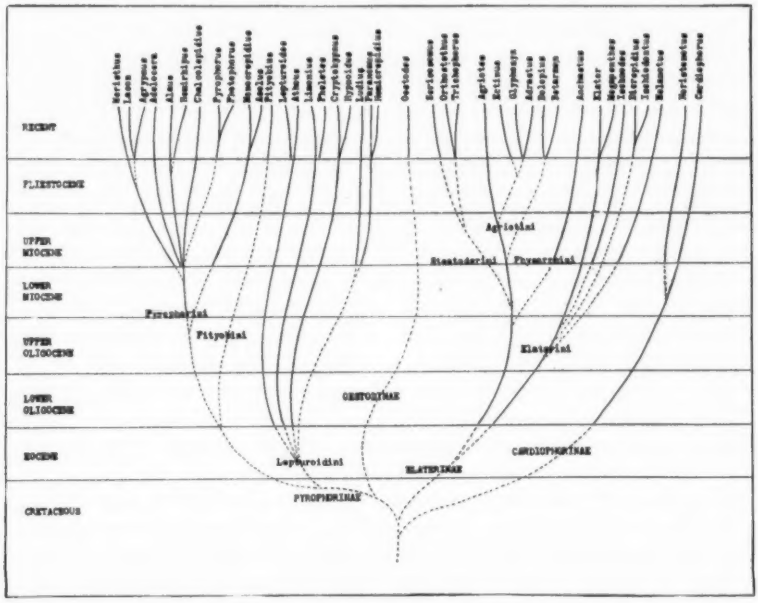

Fig. 10. Schematic Phyletic Arrangement of the Elateridae. Solid lines indicate known geologic time that genera were extent. Dotted lines are hypothetical.

Fossils having a decided Elaterid habitus are found at the base of the Mesozoic era in the Triassic rocks, these specimens, recorded by Handlirsch, bear no character, however, which can definitely place them in this family. Similar fossils are also found in the Liassic. The Jurassic chalks bear fossil insects which are decidedly elateriform, but the placing of

* Bull. Mus. Comp. Zool. LX, No. 12, p. 493–527, 1916.

such in our present genus *Elater* is hardly justified. It is probably safe to place the original Elaterid stem in the upper Jurassic. The palontological record is blank from the time of these earlier fossils until the early Tertiary. The baltic ambers of the Lower Oligocene contain Elateridæ so well differentiated as to be referable to extant genera. Eucnemidæ are very numerous, as would naturally be expected in Amber faunas. The Cardiophorinæ had already split off from the parent stock, probably in the Upper Cretaceous. The Pyrophorinæ were already differentiated into their main tribes, but what seems most remarkable is that the Lepturoidini and not the more conspicuous Pyrophorini are represented. In fact, the Pyrophorini are not recorded until the Upper Miocene where they abound in both the Oeningen beds in Europe and in our own Florissant of Colorado. This seems to indicate that our tribe Pyrophorini left the Pyrophorinæ stem at a much later period than the tribe Lepturoidini. The great gap in the record covers the period in which the greatest Elaterid diversification took place, that is in the Cretaceous and lower Eocene.

Family ELATERIDAE.

Italicized tribes and sub-tribes are tentatively placed, as larvae of species have never been described.

Subfamily Pyrophorinae
1. Tribe Pyrophorini
   - Sub tribe Agrypnina
   - Sub tribe Hemirhipina
   - Sub tribe Chalcolepidina
   - Sub tribe Pyrophorina
   - Sub tribe Monocrepidina

   Tribe *Oxynopterini*
   Tribe *Tetralobini*
2. Tribe Pityobini
   - Sub tribe Pityobina
3. Tribe Lepturoidini
   - Sub tribe Athouina
   - Sub tribe Lepturoidina
   - Sub tribe Ludiina

   Tribe *Crepidomini*
4. Tribe Oestodini
   - Sub tribe Oestodina

Subfamily Elaterinae
1. Tribe Steatoderini
   - Sub tribe Sericosonina
   - Sub tribe Steatoderina
2. Tribe Agriotini
   - Sub tribe Agriotina
   - Sub tribe Adrastina
3. Tribe Elaterini
   - Sub tribe Elaterina
   - Sub tribe Dicrepidina

   Tribe *Eudactylini*
4. Tribe Physorrhini
   - Sub tribe Physorrhina
5. Tribe Melanotini
   - Sub tribe Melanotina

Subfamily Cardiopherinae
   Tribe Cardiophorini
   - Sub tribe Cardiopherina

Subfamily Physodactylinae

Tribes not yet located:

Tribe *Allotriini*
Tribe *Dimitini*
Tribe *Hypodesini*
Tribe *Cardiorhini*

TAXONOMIC VALUE OF ANTENNAL SEGMENTS OF CERTAIN COCCIDAE.

A. H. Hollinger, Missouri Agricultural Experiment Station.

During the past two seasons the writer has been making special investigation of the *Coccidæ* of Missouri, and during that time many interesting forms, *Diaspinæ* as well as others, have been found, including several new and rare species. The *Diaspinæ*, while presenting certain problems in themselves,are not nearly so perplexing as are the mealy bugs, including *Phenacoccus*, *Pseudococcus*, and *Trionymus*, the *Eriococcids*, the *Lecania*, and other genera of the *Coccinæ*. While it is a comparatively simple matter to identify armored scale insects by means of the pygidia, it has been an almost impossible task for the average entomologist to separate the different species of the so-called soft scales, due to the fact that there have been very few constant, tangible characters for comparison in this broad group. Some writers have made a study of the fringe of setæ and accompanying gland pores surrounding the anal openings in certain of the mealy bugs (5). Others have studied the cerarii (5) which are the grouped conical spines and accompanying gland pores along the sides of certain of the mealy bugs. A few have elaborated on the structures of the anal plates of the *Lecania* (2). Many others have attempted to characterize species of *Coccidæ* by establishing a formula for the lengths of the antennal segments. While each of these may be of some value in strict systematic work, the practicability of using any one of these for easy identification of species is slight, at best. What is needed in coccidology is to put the study of soft scales upon a practical working basis, and so it was with this aim in view that the writer has given much of his time to close inspection and careful comparative study of the several genera of the native soft scale insects.

Cockerell's note (4), in which mention was made concerning the value of antennal segments in the determination of coccid species when antennal curves were plotted, led the writer to investigate this method.

There has been much debate among entomologists as to whether or not antennæ in coccids are of any taxonomic value.

Marlatt (1) stated that he had the gravest doubts as to the value of the measurements of antennal segments in the determination of species, because the antennal formulæ varied so greatly even in the same individual. Pergande (1), Smith (3), and undoubtedly many others have been misled into thinking similarly because of the apparent discrepancies which arise in the antennal formulæ of any particular species, but which, if carefully worked out by the curve method, would present a definite working basis for that species. Quoting Cockerell (4): "It does not follow, as some uncritically assume, that antennal measurements are useless" just because the antennal formulæ are so variable.

Due to the fact that no published directions for making the curves were known to the writer at the time this investigation was started, he proceeded along lines of his own initiative and used a system for the graphic representation of the antennal segments which not only shows the general trend of the individual curves, but also shows the mean curve for all the measurements of normal antennæ in any particular species.

Using millimeter graph paper, the writer laid off in succession, working downward on the vertical axis or axis of ordinates, distances of ten millimeters. Each unit of ten millimeters was let represent one antennal segment. It is needless to mention that this unit was an arbitrary one, for the writer might just as well, except for lack of space, have taken larger units. On the horizontal axis, or axis of abscissis, the lengths of the successive antennal segments were plotted, one millimeter being used to represent a length of one micron. The writer could have taken a different unit, but for the sake of simplicity and compactness, the above-mentioned one was chosen. These units have been used in all the accompanying curves, and consequently they are uniform and comparative. Connecting the points in succession along the direction of the vertical axis produced the graphic figures. In all cases under observation, these curves are distinctive and characteristic of each species the writer has studied, as a comparison of the figures will show. All figures have been photographically reduced one-half.

After having followed this system for producing the antennal curves, the writer learned, through the United States Bureau of Entomology, that Brain (6) had published a few years previously the graphic representations of the antennal segments

of certain South African species of *Coccidæ*. Reference to this paper, however, led the writer to adopt the plan of the curves as originally used, and not to adopt the method used by Brain. To the writer, as well as others who have inspected this paper, the curves shown herein are to be preferred over those of Brain's, for they give the general trend of the individual curves, the general trend of the curves of the species as a whole, and the mean curve of the species.

According to Cockerell (4): "the curves will of course vary, hardly any two antennæ being exactly alike; but except for abnormalities (pathological specimens), nearly every species gives quite different curves, while two species, very different in other respects, will give nearly the same curve. Some of the widely distributed species give curves almost too variable to be of much service, but in these cases, it is possible that the material contains more than one thing."

Brain (6) summarizes the taxonomic value of antennal segments of *Coccidæ* as follows: "The lengths of the antennal segments are of great importance in the determination of species if the measurements are accurately made from stained specimens and properly tabulated." "The most useful arrangement of antennal data seems to be arrived at by giving the range of variation in the measurements of the different segments, with the addition, perhaps, of the mode of each. After working over a large series of slides, one is impressed with the characteristic appearance of the different antennæ. But this difference is difficult to express. The nearest approach is obtained by a" graphic representation of the lengths of the antennal segments, "and this supplies a most useful aid for the preliminary location of an insect from slide specimens." "Similarity of antennal curves, while indicating similarity of antennal formulæ, does not of necessity indicate identity of species, but it does give a clue to work upon and possibly at times indicates relationships."

The writer is led to believe that these graphs are one of the main characterizing taxonomic features, and this view has been strengthened and sustained by several incidents and observations, among which the following will clearly illustrate their importance.

Several lots of *Pseudococcids* were collected by the writer, one of these in early spring of 1916 under the rough bark of

wild grape, about ten miles south of Columbia, Missouri, and the others in and around Columbia, Missouri, during midsummer upon Lactuca canadensis, L. sagetifolia, Geum canadense and Solidago stricta. Careful mounting and examination of the materials on the above mentioned annuals and on the perennial Solidago stricta readily disclosed the fact that these four lots belonged to the same species, *Pseudococcus shaferi* species novo, and the antennal graphs further substantiated this result beyond a doubt. The material from wild grape was also mounted, there being one adult female and several nymphs. The antennal graph, as first made, was misleading, due to the fact that the antennal measurements of the adult and of the young were plotted together, thus hiding the true antennal graph of the adult. So this coccid on wild grape was at first referred by the writer in his manuscript to a new species. It was only after replotting the antennal measurements of the adult's segments that the similarity to the graph of *Pseudococcus shaferi* species novo was observed. Careful comparisons of the descriptions also showed identical details, such as the alveolated posterior coxæ, the size of the leg segments, the anal ring and anal lobe setæ, the conical spines in the cerarii, the spiracles, the obscureness of the cerarii anterior to those on the anal lobes, etc., so that undoubtedly the coccid from wild grape is also *Pseudococcus shaferi* species novo. The reason for the apparent difference in food habit is that this coccid, feeding upon annuals and perennials throughout the growing season, forsakes such situations late in the fall and ascends to places which will insure dryness and protection throughout the winter and early spring and here forms its ovisac, the spring brood descending to feed upon the preferred food plants, which are either annual or perennial. Such procedure has been observed in the case of *Trionymus americanus* (Ckll.) which left its food plants—several kinds of grasses—and ascended the trunks of different species of trees late in the fall, and upon which their ovisacs were formed.

Other similar instances might also be cited, but the writer feels sure that the value of the graphic representations of the lengths of antennal segments has been clearly shown in the above cited case.

It will be noticed in the discussion of the accompanying graphs that the writer gives the antennal formula of the mean

curve of each species. While these formulæ are not considered to be of primary importance, they at least remain fairly constant for each species where a large number of measurements have been plotted. Where it was possible to use only a few measurements, the formulæ of the mean curves of those species would probably vary to a slight extent if more measurements had been used. In all cases as many measurements as possible were plotted, ranging from only two or three to over sixty.

The writer does not merely characterize the various new species of coccids upon the basis of the antennal segments alone, but in all cases they formed the working basis for their identifications. One thing worthy of note is that all the species of *Pseudococcus* known to occur in Missouri have the last antennal segment the longest, as is shown by the antennal formulæ of the mean curves of those species, or by the mean curves themselves. On the other hand, most of the remaining species do not have the distal segment the longest.

The new species of scale insects mentioned in this paper are fully described, figured, and discussed by the writer in his manuscript on the Coccidæ of Missouri. They will later be published in a Missouri Agricultural Experiment Station bulletin, so that the exact distribution, food plants, and further distinguishing characters of these new species will be forthcoming in the near future.

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EXPLANATION OF PLATES

PLATE XIX

FIGURE 1 represents the antennal curves of a new species of *Coccinæ, Exæretopus boonei* species novo which has two segments to the tarsi. The writer places it in the genus *Exæretopus* (which may be the same thing as *Luzulaspis*) because of this peculiarity. It is the only one of this genus found in Missouri. Some of the other distinguishing characters are the whip-tail gland ducts, the marginal fringe of body setae or spines, the large Sclerotinia-shaped spiracles, the anal plates, the anal ring, etc. Ulmus americana is one of its hosts. The antennal formula for the mean curve is 4831(56)72.

FIGURE 2 is the antennal graph of *Phenacoccus regnillohi* species novo. This species is further characterized by the stout, white, waxy *Orthezia*-like lamellae, by the cerarical spines, by the deep maroon color of the body, by the spiracles, etc. Ostrya virginiana is the only known host. The antennal formula for the mean curve is 93251(678)4.

FIGURE 3 is the graph of *Phenacoccus celtisifoliæ* species novo, found feeding upon the leaves of Celtis occidentalis. Although this graph bears a slight resemblance to that of Figure 5, it may be readily separated from it by the presence of simple body glands, by the cerarii, by the absence of long, glassy, hair-like filaments, by the shape of the body and by the canary-yellow color of the body. The antennal formula for the mean curve is 239154678.

FIGURE 4 represents the antennal curves of *Phenacoccus grandicarpos* species novo. It is also characterized by the large size of the adult female, being the largest species of this genus the writer has seen; by the cerarii, and by the tea-green color which results when boiled in 10% KOH. The antennal formula for the mean curve is 92178(35)64.

FIGURE 5 is of *Phenacoccus pettiti* species novo, the most common species of this genus in Missouri. This species is further distinguished by bearing many long, waxy, glassy, hair-like filaments on the dorsum, by the grayish color of the body, by the cerarii, and by the peculiar body glands. The antennal formula for the mean curve of this species is 329541678.

FIGURE 6 is the curve of *Coccus hesperidum* Linn. The antennal formula for the mean curve is 3472165.

FIGURE 7 is the graph of *Lecanium nigrofasciatum* Perg. The antennal formula for the mean curve is 362154. The over-wintering stage of this species was used for study.

FIGURE 8 shows how the antennal segments of *Saissetia oleæ* (Bern.) appear when plotted. The antennal formula for the mean curve of this species is 32(18)4567.

PLATE XX

FIGURE 9 is the graph of *Eriococcus borealis* Ckll. which the writer has found on Celtis occidentalis and Aesculus glabra. The first antennal segments are not plotted, because of the difficulty of obtaining exact measurements of the basal joints. The antennal formula for the mean curve of the adults is 342765. Figure 11 is the graph of the antennae of the nymphs of this species. The antennal formula for the mean curve of the nymphs is 732465.

FIGURE 10 shows the curves of *Coccus elongatus* (Sign.). The antennal formula for the mean curve of this species is 3218(45)67.

FIGURE 11. The legend for this is embodied in the discussion of Figure 9.

FIGURE 12 represents the curves of the common greenhouse mealy bug, *Pseudococcus citri* (Risso). The antennal formula for the mean curve is 82317654.

FIGURE 13 is the graph of *Lecaniodiaspis pruinosa* Hunter. It is a common species in this part of the country. The antennal formula for the mean curve is 435127689. The immature females with eight-segmented antennae should not be confused with the adult females, although they appear similar externally.

FIGURE 14 is the curve of *Eriococcus missourii* species novo. It is further characterized by the peculiar striped, dermal, color markings of the females. The antennal formula for the mean curve is 437256. The first segment is not considered, because of the difficulty in measuring its length.

FIGURE 15 is the graph of a variation of *Eriococcus missourii* species novo. It apparently is a six segmented form, the third joint being the longest and about equal to segments Nos. 3 and 4 of the seven segmented form. The antennal formula for the mean curve of the six-segmented form is 36254. The first antennal segments are not plotted.

FIGURE 16 is the curve of *Pseudococcus nipæ* (Mask.) a very pretty, sedentary mealy bug. The antennal formula for the mean curve of this species is 72(13)645.

FIGURE 17 is the graph of *Gossyparia spuria* (Modeer) collected on elm in Michigan. It is not indigenous to Missouri so far as the writer knows. The antennal formula for the mean curve of this species is 342756.

FIGURE 18 is the graph of *Lecanium* spp. non det. found in large numbers upon ash. The antennal formula for the mean curve is 3471265.

FIGURE 19 shows the curves of another *Lecanium*, *L.* spp. non det. found abundantly upon elm. The antennal formula for the mean curve is 3472165.

PLATE XXI

FIGURE 20 represents the antennal segments of *Pseudococcus shaferi* species novo, found upon annuals and perennials, and also hibernating under the rough, exfoliating bark of wild grape. This particular curve was formerly thought, by the writer, to belong to a distinct species, but subsequent examination and comparison of the material with that which was used to produce the curves in the next figure, showed conclusively that it was the same species. No mean curve is shown in this figure, because that of Figure 21 applies to this, as well.

FIGURE 21 is the graph of *Pseudococcus shaferi* species novo. It is further characterized by the cerarii, etc. The antennal formula for the mean curve of the adults of this species is 82137(56)4. Figure 23 is the graph of the nymphs' antennae. The antennal formula for the mean curve of the antennae of the nymphs is 632154.

FIGURE 22 is the graph of the antennal segments of *Pseudococcus jessica* Hollinger. Descriptions and figures of this species are given in the Canadian Entomologist for December, 1916, and for January, 1917. The antennal formula for the mean curve of this species is 8(12)37564.

FIGURE 23 (See legend as given under Figure 21).

FIGURE 24 is the graph of *Pseudococcus morrisonii* species novo, collected from white hickory. It is further characterized by the cerarii. The antennal formula for the mean curve of this species is 81237654.

FIGURE 25 is the graph of *Pseudococcus mcdanieli* species novo. This species is further characterized by forming an ovisac of white, fluffy filaments which often completely cover the body of the adult female; also by the seven segmented antennae, by the cerarii, etc. Ragweed, Ambrosia trifida, seems to be its most preferred food plant. The antennal formula for the mean curve is 713(24)65.

FIGURE 26 is graph of the nymphal stage of *Trionymus americanus* (Ckll.). This species is a grass feeding coccid. The antennal formula for the mean curve of the nymphal antennae is 7126435.

FIGURE 27 is the graph of the adults' antennae of the species, *Trionymus americanus* (Ckll.). This species is further characterized by having cerarical spines only on the ultimate and penultimate segments. The antennal formula for the mean curve of the adults' antennal measurements is 81273564.

PLATE XXII

FIGURE 28 is the graph of *Pseudococcus pseudonipæ* (Ckll.) collected from palms. The antennal formula for the mean curve of this species is **71246(35)**.

FIGURE 29 is the graph of the clover-root mealy bug, *Pseudococcus trifolii* (Forbes). It is further characterized by the cerarii, which occur only on the ultimate segment of the winter female. The antennal formula for the mean curve of this species is **7126435**.

FIGURE 30 is the curve of the measurements of the antennal segments of *Lecanium* spp. non det. collected only from perennials. The antennal formula for the mean curve of this species is **3427165**.

FIGURE 31 is the graph of *Pseudococcus omniverae* species novo, which is very common and omniverous in its feeding habits. It is further characterized by the cerarii, dermal characters, etc. The antennal formula for the mean curve of this species is **83215764**.

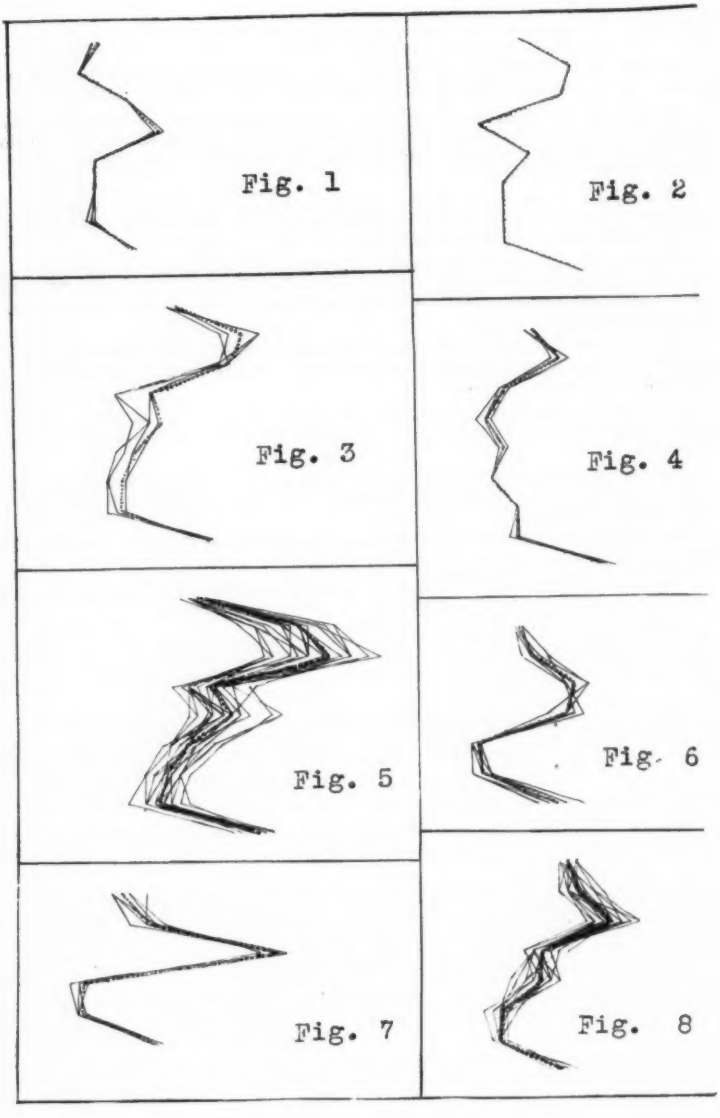
FIGURE 32 represents the curves of *Pulvinaria amygdali* Ckll., found abundantly upon the leaves of gooseberry. The antennal formula for the mean curve is **32145867**.

FIGURE 33 is the graph of a seven segmented species of coccid found on sycamore, *Lecanium* spp. non det. The antennal formula for the mean curve is **732(14)65**.

FIGURE 34 represents the golden rod *Orthezia, O. solidaginis* Sanders, a very common species around Columbia, Missouri. The antennal formula for the mean curve is **381546(27)**.

FIGURE 35 shows the curves of *Pseudococcus longispinus* (Targ.). The antennal formula for the mean curve of this species is **82315467**.

FIGURE 36 is the graph of *Pulvinaria vitis* (Linn.) the cottony maple scale. The antennal formula for the mean curve of this species is **342185(67)**.



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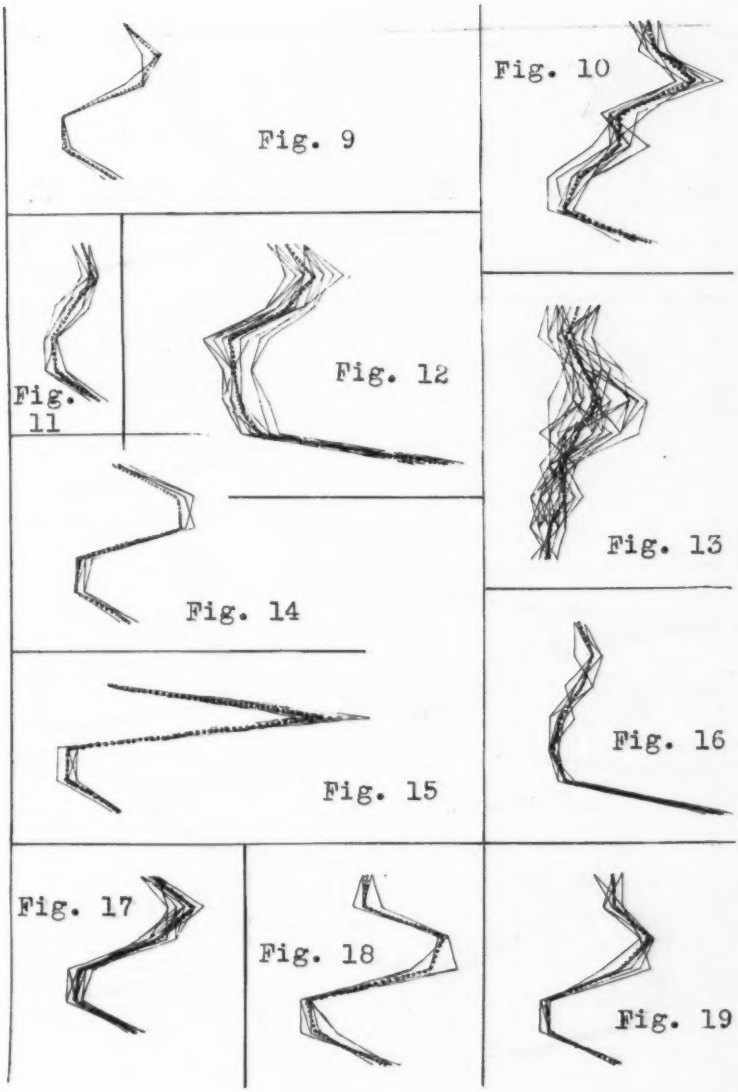

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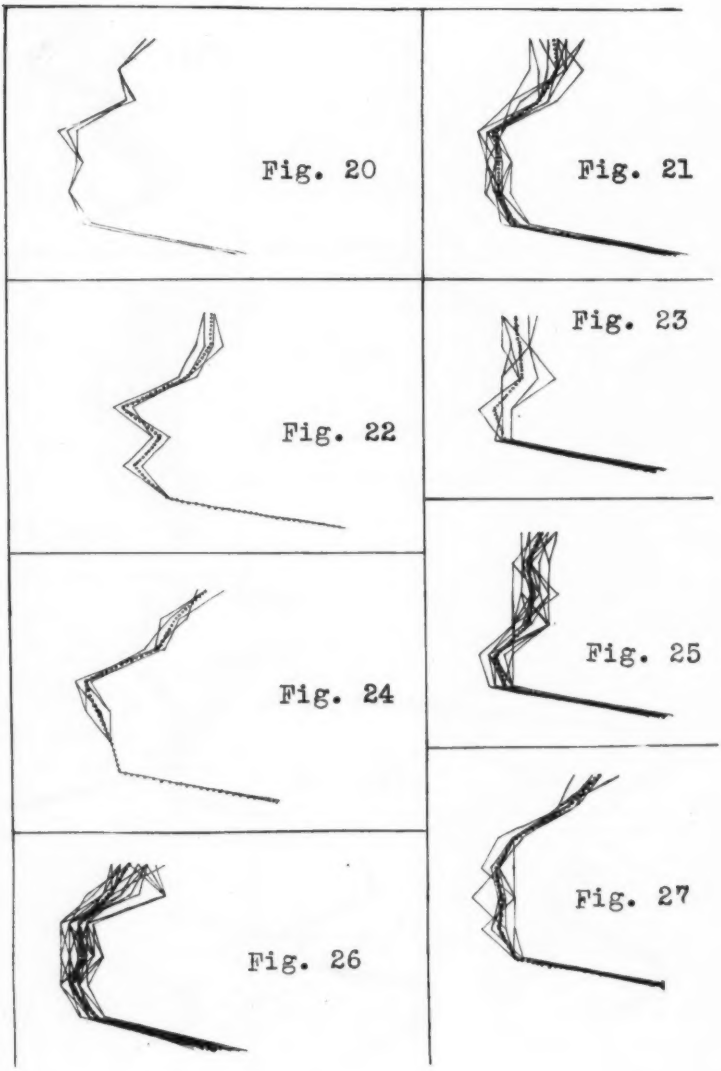

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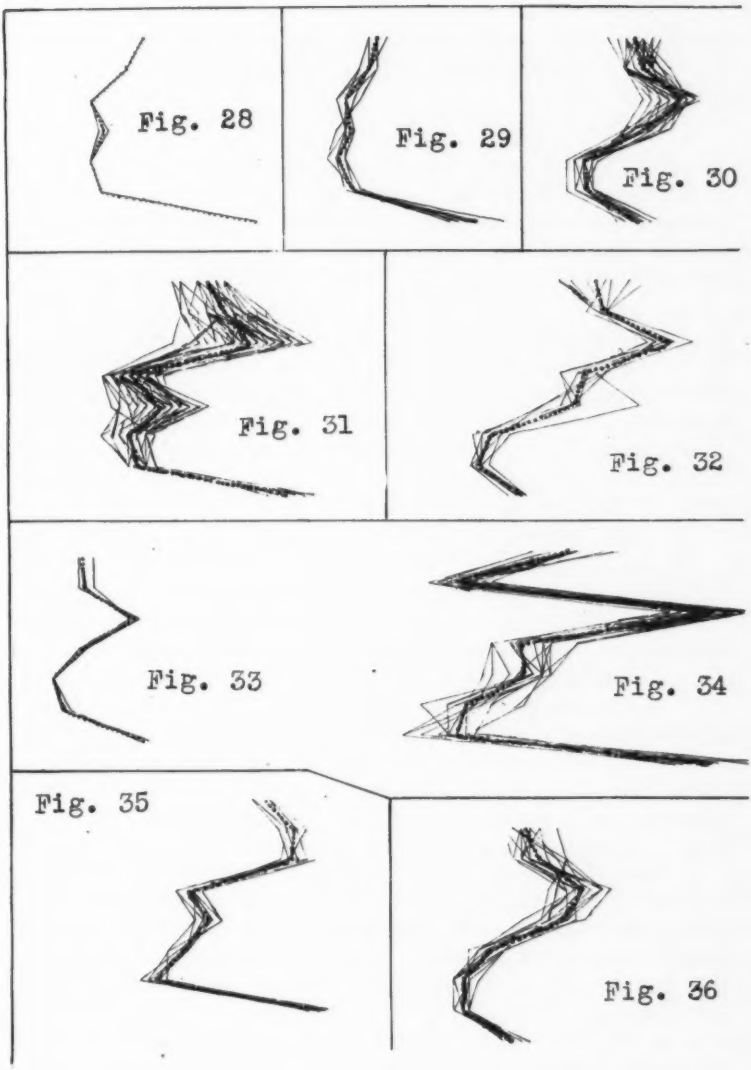

A. H. Hollinger.

NOTES ON BOMBIDAE, AND ON THE LIFE HISTORY OF BOMBUS AURICOMUS ROBT.

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Up to the present, little work has been done on the life-history of our American *Bombidæ*. Mr. F. W. L. Sladen, in his admirable book, "The Humble-bee," has given us, however, the principal facts in the life-history of the common English *Bombidæ*, besides many other observations of importance and interest.

There are several reasons to account for the dearth of literature on the subject of the life-history of bumblebees. Unlike the honey bee, all the individuals of *Bombus*, with the exception of the new queens, die in fall. The new queens hibernate throughout the winter in various situations, and issue forth in spring, to start new colonies. In order to obtain a good, clear, and accurate account of the life-history of *Bombus*, constant observations must be made, from a very early date in the history of the colony.

In spring, the nests of *Bombus* are less likely to be found than later in the season. This is mainly due to the fact that the nests are then smaller, and contain fewer bumblebees to attract attention. Many of the nests of *Bombus*, mentioned in the literature, were found and opened in late summer or fall. The opening of a nest in the late summer or fall permits only of observations regarding the size of the colony, the number of bumblebees of each caste present, the number of eggs, larvæ, pupæ, arrangement of the comb, and various other miscellaneous notes. The attempt to transfer a nest in spring or early summer from the field to an observation box, and to carry on a series of observations, is very apt to cause the queen to abandon her nest. In April, 1910, I found many *Bombus* queens of various species, occupying old, deserted nests of field mice. These nests were in an old pasture on the surface of the ground. No adults had as yet emerged in any of the nests examined, the nests containing eggs or small larvæ, or both. Not one of these nests was transferred to an observation box with success; the queen either deserting the nest after several days, or if confined,

dying within a short time. During the spring of 1916, however, I managed to transfer successfully young colonies of *B. pennsylvanicus* DeGeer from their original quarters to observation boxes.

Attracting Queens to Artificial Nests.

Mr. F. W. L. Sladen found that by burying various types of domiciles in the ground in spring, he could attract *Bombus* queens and get them to nest. This enabled Sladen to get the colony at its very inception, and then by carefully removing the nest to an especially constructed bumblebee-house, the life-history could be successfully studied.

In the spring of 1915, I tried Sladen's method, using a domicile of my own design, and had the satisfaction of finding that one of my domiciles had been selected by a queen of *B. pennsylvanicus*. This queen, however, deserted the domicile because of excessive moisture. In April, 1916, I tried the experiment again, using a slightly different type of domicile, and was more successful than before.

In one domicile, which I had placed in a clay embankment, beside a railway track, and near open woods, a queen of *Bombus auricomus* Robt. started her nest. This domicile was placed in the ground on April 15, 1916, and was observed to be occupied on June 24, 1916. On the last-mentioned date, the nest was removed to an especially constructed observation box for bumblebee nests. This nest contained, when first found, the following: nine eggs, three large larvæ, five pupæ in various phases of development, one medium-sized worker, and the mother queen. Judging from the silvery, moist, and matted appearance of the worker, the worker had only recently emerged. In addition the nest contained one empty cocoon in the center of the group of cells, and a wax-pollen honey-pot. This honey-pot was separate from the remainder of the comb and was near the entrance of the nest. The queen, at this period in the history of the colony, still retained her glossy, slick, well-kept appearance of youth.

Egg-Laying Habits of *B. auricomus*.

One of the striking habits of *B. auricomus*, noticeable at the very outset of study, was that each egg was deposited in a separate egg cell. Such a characteristic has, to my knowledge, not

heretofore been found in any species of *Bombus*. During the time that this colony of *B. auricomus* was under my observation, no eggs laid by the queen were ever deposited in batches in a single wax-pollen mass, but always in separate cells. These egg cells, or chambers, were constructed by the queen usually about twelve hours before the eggs were laid. Occasionally an egg cell was constructed, and then allowed to stand empty for several days. The queen usually laid several eggs within a period of twenty-four hours; occasionally laying more, and sometimes not laying any eggs for several days at a time. Eggs laid within a short interval of each other, were deposited in egg cells adjoining one another; thus giving the adjacent egg cells somewhat the appearance of an egg mass, but always spread out over a larger area on the surface of the comb. The place selected by the queen on which to construct her egg cells, was usually on one side, near the top of a newly spun cocoon; or in the depressed area formed between the tops of adjoining cocoons.

I have never seen a worker of *B. auricomus* making an egg cell, though there seems to be no reason why an egg-laying worker should not do so. On July 28, the mother queen was lost from the nest; her loss being traceable to the fact that she fell from the ledge at the entrance of her nest, and as her wings were clipped, could not return. For several days after the old queen disappeared from the nest, the workers were abnormally irritable, frequently biting one another, or chasing one another over the comb. On July 31, several new, empty, separate egg cells were found; and on August 2, these cells contained eggs. These last-mentioned eggs and egg cells were undoubtedly made by egg-laying workers. The stimulus that leads to the construction of an egg cell, is probably the same in both workers and queen. This stimulus is possibly due to the presence of a ripe egg in the ovaries.

On June 26, the queen laid five eggs, which is the largest number of eggs she ever laid during a single day of which I have any record. Before the queen was lost, and after the nest was transferred, she had laid thirty-seven eggs. To this total of thirty-seven eggs must be added the number of eggs, larvæ, pupæ and adults in the nest at the time the nest was taken, thus making forty-five eggs in all. The eggs are three and one-

half millimeters long and one millimeter wide; are white, sub-crescentic, tapering somewhat at one end, with both ends rounded.

General Notes on *B. auricomus*.

Within a short time after the nest had been transferred to the observation box, the queen and worker seemed to be entirely at ease, and performed their duties as if nothing had happened. Food, consisting of a mixture of honey and water, was supplied to the queen and worker in small tin containers for several days after the transference of the nest. Feeding was necessary because the bumblebees were not allowed their freedom for several days after transference.

During the early stages of the history of the colony, the queen and solitary worker applied themselves industriously to their work. Just how the queen laid her first eggs, and cared for her first brood, I was unable to observe, as the nest was not taken in time; but the procedure probably does not differ essentially from that followed at a later date. The queen and her worker devoted much of their time to the tasks of feeding the larvæ, and of brooding over the comb, especially that part containing the egg cells. While brooding over the comb, the queen frequently and intermittently made a loud purring noise, accompanied by a sharp twitching of the wings. This purring of the queen could frequently be heard almost sixteen feet from the nest. On June 28, two more workers, both somewhat larger than the first worker, emerged within twelve hours of each other. On July 7, there were eight workers in the nest, all of which had emerged about a day or so apart. Such an irregularity in the rate of emergence of the first few workers, tends to support my belief that the first eggs laid by the queen of this species are laid separately, and at different intervals; instead of several eggs being laid at the same time in one batch.

In order to examine the eggs and young larvæ, the queen and workers were often removed from the nest, and then later returned. If one tried to open a cell while the queen or workers were around, the bumblebees would attack the forceps used in the operation, and bite them with their mandibles. Again, the bumblebees would cover over the cells, almost as fast as I could pry off the coverings without danger to the cell contents.

Every morning for about two weeks, I found that it was necessary, in order to see the contents of the nest, to remove a covering of grass, compactly held together by means of a mixture of pollen and wax. This grass covering, or roof, made by the bees naturally serves to keep light from entering the nest, for general protection, and as an aid in keeping the temperature within the nest constant.

The Egg Stage of *B. auricomus*.

From this colony of *B. auricomus*, drones, workers, and queens were reared, under observation, from the egg to the adult stage. My notes show that the number of days in each stage of development, in all three castes, is subject to variation. Nutrition and temperature undoubtedly play a very important part in the lengthening or shortening of the various stages. The egg period varied from four to six days. No special, consistent variation in the duration of the egg stage of the three castes was noticeable, but additional data may prove the contrary. Mr. F. W. L. Sladen found that, as in the case of the honeybee, eggs laid by workers produced drones. I was unable to find out what finally happened to the worker eggs in this nest, but I am sure that if the eggs ever hatched into larvæ, these larvæ never reached the adult stage, on account of the lack of food. As already stated, the eggs laid within short intervals of each other, were laid in separate, adjoining cells, and these cells were spread out over the cocoon or cocoons as a single, more or less flattened mass. From the same egg mass all three castes frequently emerged.

The Larval Stage of *B. auricomus*.

The larval stages of all three castes also present striking variations in duration. The average number of days spent in the larval stage for the three castes in this nest was as follows: drone, eleven and three-fourths; worker, thirteen and a fraction; queen, eleven and a fraction. Too few bumblebees of all castes were carried through from the egg to the adult stage to enable me to say that there is an average difference in the number of days spent by the three castes in the larval stage. The larvæ grow rapidly, and usually after four days or more, spin silken threads. As these silken threads hold together the thin walls of their cells, they are essential to the existence of the larvæ.

Any eggs or larvæ which may fall from their cells to the lower combs or floor of the nest, are carried out of the nest by the workers. The larvæ are fed on pollen and a fluid prepared by the queen and workers. Mr. Sladen (*The Humble-bee*, p. 28) says that this liquid food is a mixture of honey and pollen. In cells containing larvæ more than half-grown, a small hole is visible in the top of the cell. Through this opening, which is often the size of a common pin-head, the rapidly growing larvæ are fed. After a larva has just been fed, by pulling back the upper covering of the cell, one can see the liquid food injected by the queen or worker. This liquid food is often deposited in the hollow formed in the center of the curled larva, the larva of this species at this stage of development resting on one side. Before changing to a pupa, however, the larva assumes an upright position; the head end, which is at the top of the cocoon, being bent over and downward. Dwarf adults are, at least in many cases, the result of improper feeding, due to a bad position in the comb. Whether the workers and queens are the results of special feeding, as in the case of the honey bee, I am unable at present to say. The full grown larvæ of *B. auricomus* average 26 mm. in length and 6 mm. in width. The larva has a delicate, white skin, and presents in general, except in being much larger, the appearance of the larva of the honey bee. The fully grown larva spins its cocoon about three days before pupation.

After the cocoon is spun, the wax and pollen still clinging to it are removed by the workers or queen. The size of the cocoon enables one, in many instances, to separate the cocoons of the various castes from one another. The cocoons are light yellowish brown in color; thin-walled, and lack somewhat the toughness of the cocoons of *B. pennsylvanicus*. The following is a table of measurements of the cocoons of all three castes.

LARGEST COCOON.

Drone	13 mm. wide and 19 mm. high.
Worker	12 mm. wide and 15 mm. high.
Queen	15 mm. wide and 23 mm. high.

SMALLEST COCOON.

Drone	11 mm. wide and 17 mm. high.
Worker	7 mm. wide and 13 mm. high.
Queen	13 mm. wide and 21 mm. high.

AVERAGE COCOON.

Drone	12 plus mm. wide and 18 plus mm. high.
Worker	9 plus mm. wide and 14½ plus mm. high.
Queen	13½ plus mm. wide and 22 plus mm. high.

The pupal stage also presents variations in length. The average time spent by the three castes, in the pupal stage, was as follows: drone, nine and a fraction days; worker, nine and one-half days; queen, eleven days.

The Adult Stage of *B. auricomus*.

When the adult is ready to emerge, a slight movement within the cocoon is noticeable. An adult escapes from its cocoon by cutting around the cap of the cocoon and pushing up the lid thus formed. Frequently, the emerging adult is assisted in escaping from its cocoon by a worker or the queen. Immediately after emerging, the adult makes a search for the nearest supply of honey. A newly emerged bumblebee has a moist, matted, velvety appearance. That portion of the pubescence which is black in the older adults of this species, is in the young adults light gray, occasionally approaching a dark brick-red; those portions which are yellow in the older adult, being very pale, almost white, in the freshly emerged specimens. Adults seldom leave the nest until their pubescence has reached its normal color.

The first adult bumblebee to emerge is probably always a worker; at least in this nest, such was the case. The second worker emerged on June 26, the first drone on July 22, and the first queen on July 24. The drones of *auricomus* appear early in the season as compared with those of most other bumblebees.

Storage of Pollen and Honey.

For the first few days after emerging, the workers brood over the eggs, attend to the wants of the larvæ, clean out empty cocoons, and perform all those miscellaneous duties involved in a social type of existence. After that, besides helping within the nest, the workers usually leave the nest in search of pollen and nectar. On returning from a successful foraging trip, the honey is regurgitated either into the original honey-pot, or into empty cocoons used for the same purpose. Cocoons used for the storage of honey are capped over with wax. The pollen is scraped from the corbicula into empty cocoons used for that purpose. Before a worker scrapes off her load of pollen, she pokes her head into various empty cocoons, until she finds the right one for her purpose. After the pollen-containing cocoon has been found, the worker stands on the edge, facing away

from the cocoon, and inserts her hind legs down into the cocoon; then she proceeds by a quick, slicing, downward movement of the middle pair of legs, to remove the pollen from the corbicula. The spur on the end of the middle tibia probably serves as a lever to remove the pollen from the pollen-plate. The habit of storing pollen in empty cocoons away from the larval mass, would cause this species of *Bombus* to be classed as a "pollen-storer" by Sladen (Ent. Mon. Mag. 1899, p. 230). The pollen pellets once deposited, are then packed down by the same worker or by other workers; the head and mandibles being used in this operation.

Manipulation of Wax.

Wax is produced by the females between the basal abdominal segments as Sladen also found. The color of the pure wax is white. The wax is scraped from the dorsal parts of the abdominal segments by the hind legs, which are drawn down and over the abdomen; the inner sides of the hind metatarsi serving as brushes. After the hind legs have been drawn over the dorsum of the abdomen, the bumblebee stands on her fore- and middle-legs and rubs the inner surfaces of the hind tarsi together with an up and down motion. This rubbing of the inner surfaces of the hind tarsi removes the particles of wax, which fall down on the comb. Many times I have watched bumblebees scrape the wax from their tarsi in the manner described, and have never seen one select any particular spot for depositing it. It may be mentioned, however, that the wax is usually removed while the worker or queen is standing on the brood or egg cells. The particles of wax, after being dropped, are later usually picked up by other bumblebees and worked into the surrounding comb. Wax was produced in large quantities by the old queen, but I never found signs of wax on the new queens. Wax was never noticed on the workers until after the normal color of the pubescence had been assumed.

One queer feature of this nest was the addition of a number of cells similar in structure to the original honey-pot, and attached to the latter. On July 7, eight other cells had been added to the original honey-pot, making nine in all. Later some of these cells were destroyed by the workers, and the material transferred to another part of the comb. Of these nine cells, six were not used for any purpose, pollen was stored in one,

and honey kept in two others. The original honey-pot measured on July 3, twenty millimeters in height and seventeen millimeters in width.

Habits of the Drones and Queens.

The drones, besides fertilizing the queens, do not contribute much to the welfare of the colony. After emerging, the drone of this species stays in the nest for several days; then flies out, sometimes returning and sometimes not. While in the nest the drones are very alert, and always retreat to the bottom of the nest at the first alarm. On several occasions I have seen the drones assist in brooding over egg and larval cells. The males of *B. auricomus* have very large eyes which, together with several other characteristics, caused this species, along with others, to be placed by Robertson in a new genus *Bombias*. (Trans. Amer. Ent. Soc. Vol. 29, 1903, pp. 176, 177.) Dr. H. J. Franklin, however, does not accept *Bombias* as a valid genus, regarding it instead as a subgenus. (*Bombidæ of the New World*. Trans. Amer. Ent. Soc., Vol. 38, 1913, p. 410.) I have seen the drones of this species hovering for hours about a particular fence-post in the sun, and from there darting out from time to time. On one occasion, I tried for two successive days to catch a male of this species which persisted in alighting on a particularly high weed in a sunny situation, and was at length successful. Here also, it may be mentioned that *B. separatus* Cress., another member of the subgenus *Bombias*, with large eyes, has the same habit of selecting fence-posts, trees, and other prominent objects, and remaining about them for many hours. I have never seen a male of *B. auricomus* attempt to copulate with a queen in the same nest.

The new queens assist in the general work of the nest, and seem to get along very well together. The queens are probably fertilized by the males after leaving the nest. Hibernation of the young fertilized queens undoubtedly occurs, but I have never found a hibernating queen of this species, nor do I know of one having been found.

Remarks on Habits.

Of the several species of *Bombus* with which I have been working, *B. auricomus* has the smallest colony, is the most easily handled, and is the most cleanly in its habits. The fæces are

always deposited either outside the observation box, or in a far corner of the nest. When examining the comb in the observation box, I frequently removed all the glass covers, without danger of alarming the inmates or of being attacked by them. Of course, if one were to breathe into, or jar the nest, the workers would be aroused to action. It was evident that this species could be bullied by another species of *Bombus*, when one morning I discovered a worker of *B. pennsylvanicus* running about on the comb of this *B. auricomus* nest, and helping herself to honey. The *auricomus* workers were aware of the presence of this alien bumblebee, but acted as if afraid to attack the invader. On the other hand, when a worker of *auricomus* is introduced into a nest of *pennsylvanicus* it is immediately attacked and killed.

B. auricomus is probably victimized by most of the common parasites of bumblebees, but whether any species of *Psithyrus* infest the nests I am unable to state. One worker, which I found dead on the floor of the nest one morning, contained a full grown larva of Conopidæ, *Zodion obliquefasciatum* Macq. in her abdomen. Mites of the family *Gamasidæ* were also found in the nests.

In central Illinois, *B. auricomus* is not a very common species of bumblebee.

EXPLANATION OF PLATES.

Plate XXIII.

Fig. 1. View of the nest of *B. auricomus* Robt. on June 27, 1916, showing: *a*, queen; *b*, workers; *c*, original honey pot. Reduced.

Fig. 2. View of the nest of *B. auricomus* Robt. on June 27, 1916, showing: *a*, queen; leaving the nest; *b*, worker brooding on egg cells; *c*, cocoon full of honey, partly capped with wax; *d*, first empty cocoon, containing pollen; *e*, empty egg cell. Reduced.

Plate XXIV.

Fig. 3. View of the nest of *B. auricomus* Robt. on June 27, 1916, showing: *a*, empty cocoon from which first worker emerged; *b*, original honey-pot; *c*, wax-covered cocoon; *d*, small brood cells. Natural size.

Fig. 4. View of the nest of *B. auricomus* Robt. on July 7, 1916, showing: *a*, first empty cocoon; *b*, brood mass, containing medium-sized larvae in separate cells; *c*, cocoon full of honey, partly capped with wax; d, original honey-pot; *e*, extra cells added to original honey-pot; *f*, wax-covered cocoons. Natural size.

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